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VOL. 25 AUGUST, 1932 No. 4

Proceedings of the Seventh Annual Meeting of the Cotton States Branch, American Association of Economic Entomologists

The seventh annual meeting of the Cotton States Branch was held at Birmingham, Alabama, on February 3, 1932. The program, scheduled for two days, was completed on the first day of the meeting by dividing it into two sessions. Fourteen papers were presented, classified as follows:

Insects Injurious to Cotton	8
Insects Injurious to Peaches	5
Miscellaneous	1

The Branch held a joint meeting with the parent Association in New Orleans, La., on December 31, 1931. That reduced the attendance at the Birmingham meeting.

PART I. BUSINESS PROCEEDINGS

In the absence of the chairman, the meeting was called to order by Past-Chairman J. M. Robinson at 2:00 p. m. on February 3 in the Tutwiler Hotel at Birmingham, Alabama. On behalf of the Department of Zoology-Entomology of the Alabama Polytechnic Institute, Prof. Robinson, in a few well-chosen words, presented to the Cotton States Branch a beautiful gavel made of Ciruelillo, the most precious wood in Central America. The reports were then called for as follows:

REPORT OF THE TREASURER

Balance on hand February 6, 1931	$101.80
Refund from parent Association for expenses ending February 5, 1931	22.63
Contributions from five entomologists	5.00
1929 annual dues from 10 members	10.00
1930 " " " 18 "	18.00
1931 " " " 54 "	54.00
1932 " " " 11 "	11.00
1933 " " " 1 "	1.00
1934 " " " 1 "	1.00
1935 " " " 1 "	1.00
1936 " " " 1 "	1.00

Refund from W. E. Hinds for expense in connection with entomologists' dinner at New Orleans		3.83
Paid out:		
Stamped envelopes	$ 21.38	
Stamps	2.00	
Printing announcements and programs	9.25	
Deficit on entomologists' dinner at New Orleans (By action of Executive Committee)	25.55	
Loss in Citizens Bank of Fort Valley, Ga., which failed in November, 1928	11.96	
	$70.14	$230.26
Balance on hand February 4, 1932	$160.12	
	$230.26	

REPORT OF THE SECRETARY

The number of members in the Cotton States Branch on December 31, 1931, was 236. There was a net decrease of 2 members during the year, after dropping those who had moved out of the Branch territory or who were dropped by the parent Association for non-payment of dues. Therefore, the membership is holding up well during the depression. The membership has grown from 158 to 236 in the last five years or a net increase of 78 members, after dropping those who had moved out of the Branch territory during that period or had not kept up their dues in the parent Association. So the number of new members added to the Branch roll during the last five years was even more than the number represented by the increase in the Branch membership.

The number of members by states at the close of 1931 was as follows: Texas 51; Mississippi 37; Louisiana 33; Florida 26; Georgia 20; North Carolina 19; Tennessee 18; Alabama 10; South Carolina 10; Arkansas 8; Oklahoma 4. The following states showed net increases during the year: Texas 3; North Carolina 3; Alabama 1; Mississippi 1. The following states showed net decreases during the year: Louisiana 3; South Carolina 3; Florida 2; Georgia 1; Tennessee 1. There was no net change in the number of members in Arkansas and Oklahoma.

There are now 495 entomological workers in the 11 Cotton States who are not members of the American Association of Economic Entomologists, and members are urged to assist in continuing our efforts to strengthen the Branch by increasing the membership.

Complying with a rule of the Branch, your Secretary sent to each member an invitation to participate in the joint meeting with the parent Association in New Orleans, La., on December 31, 1931, and in the regular annual meeting in Birmingham, Ala., on February 3 and 4, 1932. The program for the Birmingham meeting was mailed to each member of the Branch before that meeting.

The program for the joint meeting in New Orleans was arranged and provided by the Branch. The Branch sponsored the 11th annual entomologists' dinner and made the arrangements and provided the entertainment for the occasion. It was given in honor of Dr. Herbert Osborn on the night before the joint meeting, and proved to be a most enjoyable event.

At a business session of the Branch in 1928 annual dues of $1.00 were established. Fifty-seven members have paid their 1929 dues, 56 have paid their 1930 dues, and 58 have paid their dues for last year. Only 11 members have paid their 1932 dues. One member has paid up until 1937. The dues for this year are now payable.

The Executive Committee reported the action taken at a meeting of that committee in New Orleans to pay the deficit of $25.55 on the entomologists' dinner which was sponsored by the Branch. This deficit resulted from a smaller attendance than expected.

Acting Chairman Robinson announced the committee appointments as follows: Nominations, A. L. Hamner, G. F. Moznette, and J. M. Robinson. Resolutions, J. W. Folsom, H. S. Swingle, and W. C. Nettles. Auditing, H. S. Swingle, J. W. Folsom, and G. F. Moznette. The following standing committee was announced: Publications, Oliver Snapp and Herbert Spencer.

Final Business

The Publications Committee called attention to the fact that an abstract must accompany all papers presented for publication, and instructed those who read papers at the meeting to send them with abstract to the Secretary at the earliest date if they had not already been turned in.

The Auditing Committee reported that the Treasurer's accounts had been audited and found to be correct, and suggested that one hundred dollars of the balance on hand be deposited in postal savings. The report was accepted and adopted by motion and vote.

The following report of the Resolutions Committee was adopted by motion and vote:

"*Resolved:* That the Cotton States Branch expresses its appreciation to the management of the Tutwiler Hotel for making the excellent arrangements for the meeting.

"The Branch extends its thanks to the Mississippi A. & M. College for the use of a stereopticon."

The Nominations Committee presented the following names for officers during the ensuing year: Chairman, J. W. Folsom, Tallulah, La.; Vice Chairman, R. W. Leiby, Raleigh, N. C. These officers were duly elected. Secretary-Treasurer Oliver Snapp was elected last year for a three-year period.

The matter of changing the name of the Branch to Southern States Branch came up for discussion. Finally, by motion and vote, the change was favored but final action was withheld until the next annual meeting so that all members can be notified of the contemplated action.

The Branch voted to hold the next annual meeting with the Association of Southern Agricultural Workers in New Orleans, La., February 2 and 3, 1933.

PART II. PAPERS

The session for the presentation of papers convened immediately following the business session with Acting Chairman Robinson presiding.

BIOLOGY OF THE PINK BOLLWORM AT PRESIDIO, TEXAS

By W. L. Owen, Jr., *Entomologist, Texas Agricultural Experiment Station*, and S. L. Calhoun, *Junior Entomologist, Division of Cotton Insects, Bureau of Entomology*

Abstract

The following paper presents a brief summary of the more important findings concerning the life cycle and seasonal history of the pink bollworm (*Pectinophora gossypiella* Saunders), as studied at Presidio, Texas.

No studies on the biology of the pink bollworm (*Pectinophora gossypiella* Saunders) had been made in the United States at the time the study of this cotton pest was undertaken as a project by the Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology of the United States Department of Agriculture in 1928. It was necessary to have complete information concerning all phases of the life cycle and seasonal history of this species in order to develop measures for control. Presidio, Texas, was selected as the place for making these studies because the pink bollworm was more abundant there than at any other locality in the United States. While a few observations on the biology were made in 1928, emphasis was not placed on this phase of the work until 1929. Most of the time during the latter year was spent in developing technique. In 1930, however, a considerable amount of data were secured, the results of which are presented in this paper. In addition, some important information secured from the more elaborate experiments of 1931 is also included.

Records of rainfall and temperature for Presidio, Texas, have been taken only since 1928 and the four years' data are not sufficient to determine the normal. During this period the annual rainfall ranged from 7.50 inches in 1928 to 9.95 inches in 1931. While fairly heavy precipitation may occur during any month, the heaviest rainfall usually occurs from July to October. During the years that these studies were

being made, the maximum temperature recorded was 112°F. in June, 1928, and the minimum was 10°F. in December, 1929. Temperatures of 100°F. or above were recorded as early as March and as late as October, but occurred frequently from June to September.

The data which are presented in the following discussion on life history were taken from observations made in a screened insectary and in cotton fields and were closely correlated with temperature and humidity records.

Emergence of Long-Cycle Moths.[1] Three years' records show that the period and rate of emergence of long-cycle moths were governed very largely by temperature and rainfall during the spring. Emergence of these moths began March 27, 1928, April 2, 1929, and April 11, 1930. March, 1928, was unusually warm and this undoubtedly stimulated an earlier pupation, which resulted in an earlier moth emergence than usual. During all three years, the peak occurred at markedly different dates, as follows: April 25, 1928, May 11, 1929, and June 13, 1930. The emergence took place in two general periods in 1930, the peak of the first being May 3 and of the second, June 13. While most of the long-cycle moths had issued by late June, a few continued to emerge until midsummer, the last dates recorded being July 2, 1928, August 14, 1929, and August 12, 1930.

Moth Longevity. The first long-cycle moths emerged several weeks before cotton was planted and therefore a study of their longevity was made in order to ascertain if they could live long enough to lay eggs on the cotton plants after fruiting began. These observations on moth longevity were made by confining freshly emerged moths in large lantern globes, the tops of which were covered with coarse-mesh cheesecloth. The bases of these globes rested upon soil within regular flowerpots, which were 6 inches deep and 7½ inches in diameter at the top. From 6 to 10 moths were placed in each cage and daily examinations were made to determine the mortality. It was determined that they lived but a few days under the above-described cage conditions in the insectary at this time, and also after cotton was up but before it produced squares. Their length of life was increased somewhat by the addition of water to the soil or by other available water. Where moths were kept in these cages with dry soil and no water was available, the average longevity was 3.11 days for females and 2.45 days for males, the maximum recorded for each sex being 5 and 4 days, respectively. In cages with

[1]Long-cycle moths are those emerged from pupae transformed from overwintered long-cycle larvae.

wet soil, however, the females lived for an average of 8.76 days, and males for 6.75 days, the maximum record for each sex being 19 and 22 days, respectively. A solution of sugar supplied to the moths at this time did not, so far as could be ascertained, increase their length of life.

After fruiting of cotton began and moths were supplied daily with fresh cotton "slips"[2] and sufficient moisture, longevity increased perceptibly. The average longevity of female long-cycle moths under these conditions was 11.62 days, while the maximum was 24 days. The average length of life for the males was 9.94 days and the maximum was 24 days.

The length of life of the short-cycle moths[3] was greater than that of the long-cycle moths. The average longevity for females of the former type was 15.10 days and the maximum was 37 days, while for males the corresponding figures were 11.95 days and 31 days. The greater average longevity of the short-cycle moths may be partly accounted for by the fact that the above averages also include records taken during October and November when it is known that the moths live longer. Since no long-cycle moths were under observation during the latter months, the longevity records for the two types are not comparable. It is shown later, however, that the short-cycle moths had a greater vitality and their reproductive powers were also much greater than those transformed from overwintered larvae.

Period and Rate of Oviposition. Oviposition at no time began before the second night after emergence and in one instance did not begin until the tenth night. The greatest number of females began laying on the third night after emergence. No oviposition was recorded before 8 p. m., which is about dusk at Presidio, Texas. The largest number of eggs were laid between 8 and 10 p. m., a few between 10 p. m., and 12 midnight, and still fewer between 12 midnight and 8 a. m. No females were observed ovipositing during the day. The period of egg deposition for long-cycle moths ranged from 2 to 13 days and averaged 5.94 days, while for short-cycle moths the range was from 2 to 15 days with an average of 7.83 days. Death soon followed completion of oviposition, the moths dying usually in from 1 to 4 days.

The greatest average number of eggs laid in any 12-hour period were deposited on the first night of oviposition, and there was a gradual falling off in the rate of egg deposition for each succeeding night until oviposition ceased. The average number of eggs deposited by long-

[2] A "slip" is a portion of a cotton branch with leaves and young squares.

[3] Short-cycle moths as here discussed are those which emerged from pupae transformed from larvae developed in bolls during the current year.

cycle females laying fertile eggs was 105.89 and the maximum was 289. Likewise for short-cycle moths the average was 180.72 eggs, and the maximum was 448. These figures serve as a very good index to the superior vitality of the short-cycle moths, which has been previously pointed out as indicated by their increased longevity.

INCUBATION PERIOD. Incubation records were kept daily. Each morning eggs were removed from the oviposition cages and placed on blotters in small stender dishes. The blotters were dampened at intervals to provide moisture for hatching. The majority of eggs hatched in 4.5 days at a mean temperature of 83.04°F. The shortest average period of incubation was 4.25 days at a mean temperature of 84.69°F., and the longest, 25.5 days at 53.20°F. There was a general speeding up of incubation as the mean temperature increased above 58.80°F., and below this point there was a very decided lengthening in the duration of the egg stage. No records are available concerning the effect on incubation of mean temperatures above 84.69°F.

HATCHING AND FEEDING PERIODS OF LARVAE. Immediately upon hatching, the young larvae became very active in search for food and they covered distances rapidly. If cotton bolls and squares were available, they began burrowing their way into them within a short time. The duration of the larval feeding period was governed by temperature and type of food. In cotton squares the minimum period was 6 days, the maximum 18 days, and the average 10.09 days. In cotton bolls the minimum was 11 days, the maximum 25 days, and the average 16.54 days. The above averages were computed from records taken from June to November, 1931, and were obtained by egg or larval transfers to growing bolls or squares in the cotton field. Two larvae or eggs ready to hatch were placed on each square and six larvae or eggs on each boll. The bolls and squares were then covered by small cellophane bags, to prevent any outside infestation. When or just prior to the time feeding had been completed, the bolls and squares were removed from the plant and taken into the insectary, where observations on the other phases of the life cycle were made.

PREPUPAL AND PUPAL PERIODS. An average prepupal period of 3.75 days was recorded for larvae which had fed in squares, the range being from 1 to 10 days. The duration of the pupal period for these larvae ranged from 6 to 24 days and averaged 8.12 days. For larvae which had fed in bolls, the prepupal period averaged 3.28 days, the duration ranging from 1 to 21 days. The pupal period for these larvae averaged 8.61 days, the duration ranging from 7 to 14 days.

TOTAL LIFE CYCLE. Other conditions being equal, the duration of the

total life cycle, or the period elapsing from deposition of eggs to emergence of moths, depended upon whether the larvae had fed in squares or in bolls. When larvae had developed in squares, the life cycle averaged 26.60 days, with a minimum of 21.5 and a maximum of 47.5 days. On the other hand, when larvae had fed in bolls, the life cycle averaged 32.93 days, with a minimum of 25.5 and a maximum of 59.5 days.

Field Generations. During the season of 1931 six complete generations were recorded in squares, with only three and a partial fourth in bolls. As soon as cotton began fruiting at Presidio, in late May or early June, long-cycle moths began oviposition, usually on the young squares, on the under surfaces of leaves, or on the buds of the cotton plant. The first generation and a portion of the second generation completed their life cycle under field conditions with squares as food. After bolls had grown to a sufficient size for feeding, most of the eggs were laid beneath the involucre of the boll, and although some development continued in squares, the majority of the larvae fed in bolls until early October. At this date the cotton plant had matured most of its bolls, a new growth had begun, and fresh squares were set. The development in squares again increased at this time, owing to the lack of suitable green bolls and to a very heavy boll infestation.

Long-Cycle Larvae. The developmental period of the larva may take place in the square, which may bloom before the worm is quite full grown; in the green boll, which may not open until after the larva has cut its way out; or in the more mature boll, which usually opens before feeding has been completed. At Presidio long-cycle larvae appeared first in open bolls, then in green bolls, and finally in squares. The first larvae of this type were observed in the insectary in early October, 1930, and September 21, 1931. In the latter year no larvae from squares of the fourth and fifth generations were observed going into the overwintering stage. All of the fourth-generation larvae from bolls and a few from the sixth generation from squares were of the long-cycle type. While the first long-cycle larvae did not make their exit from green bolls in the insectary until September 21, 1931, field collections proved that they were present in open bolls as early as September 16. This was discovered by means of periodic collections of open bolls. Beginning with September 16, 300 newly opened bolls were collected from the field at approximately 10-day intervals until October 26. One hundred of these were examined immediately for the presence of mature larvae and 200 were saved for later examination after frost. Overwintering larvae were discovered in these open bolls after frost for each date of collection. September 16, 55.0 per cent of the larvae in open bolls were of the long-

cycle type. The proportion of the resting-stage larvae in newly opened bolls to the total number of those present in these bolls on the other dates of collection ranged from 54.11 to 75.08 per cent. The numbers of both short and long cycle larvae present in open bolls increased with each date of collection until October 26. Since over half of the total number of larvae in open bolls which were picked September 16 were of the long-cycle type, it is evident that they appeared in the field at a considerably earlier date.

SUMMARY

The period and rate of emergence of long-cycle moths was governed largely by temperature and rainfall. The peak of the emergence also occurred at markedly different dates as follows: April 25, 1928, May 11, 1929, and June 13, 1930.

Available moisture and the addition of fresh cotton plant "slips" to cages increased the longevity of long-cycle moths considerably. Short-cycle moths lived for a longer period of time than long-cycle moths.

The majority of females began oviposition on the third day after emergence and the largest average number of eggs laid during any 12-hour period were deposited on the first night of oviposition. Short-cycle moths possessed greater vigor and higher reproductive powers than long-cycle moths.

Most of the eggs hatched 4.5 days after deposition at a mean temperature of 83.04°F. The feeding and pupal periods were of shorter duration for larvae which fed in squares than for those which fed in bolls. This affected the duration of the total life-cycle, which averaged 26.60 days for the former as compared with 32.93 days for the latter.

In 1931 six complete generations were developed in squares but only three and a partial fourth in bolls. Long-cycle larvae appeared first in open bolls, then in green bolls and finally in squares. In open bolls, 55.0 per cent of the larvae were of the long-cycle type September 16, 1931.

HOST PLANT STUDIES OF THE PINK BOLLWORM

By C. S. RUDE, *Assistant Entomologist, Bureau of Entomology*

ABSTRACT

At Tlahualilo, Mexico, in the State of Durango, the following species of native, wild, malvaceous plants were found to be host plants of the pink bollworm of cotton (*Pectinophora gossypiella* Saunders), namely: *Hibiscus cardiophyllus* Gray, *Hibiscus coulteri* Gray, and *Hibiscus denudatus* Gray. Two species of cultivated malvaceous plants were also recorded as host plants, namely: okra (*Hibiscus esculentus* L.), and hollyhock (*Althaea rosea* L.). The comparative importance of these plants in main-

taining pink bollworm infestation in the absence of cotton is discussed, together with notes on distribution and habitat.

Studies of the host plants of the pink bollworm (*Pectinophora gossypiella* Saunders) were begun in northern Mexico in August 1928 and have been continued through the growing season of 1931. Most of the laboratory work was done at Tlahualilo, Mexico, in the State of Durango. Field observations were made in the desert and mountainous country surrounding this village. Three species of wild, native, malvaceous plants were studied, as follows: *Hibiscus cardiophyllus* Gray, *Hibiscus denudatus* Gray, and *Hibiscus coulteri* Gray. Notes were also made on the susceptibility of two species of cultivated malvaceous plants to pink bollworm infestation, namely: okra (*Hibiscus esculentus* L.) and hollyhock (*Althaea rosea* L.). The purpose of the studies was to determine (a) whether or not the pink bollworm could develop throughout all its stages, from egg to adult, in fruiting buds or capsules of these plants during the growing season, (b) if this species could successfully hibernate in the fruiting capsules of these plants, and (c) whether or not moths emerged from long-cycle larvae which had overwintered in seed capsules of these wild host plants could reinfest these plants.

In all of the tests, wherever possible, the moths were reared and the determinations verified.[1] In all cases the life cycle stages of the pink bollworm transferred to Hibiscus were taken or reared from cotton. Since the tests conducted differed somewhat for each species of host plant studied, the technique used is described briefly in connection with the discussion of each plant.

Hibiscus cardiophyllus Gray

This plant is a perennial, sparingly branched, low shrub attaining a height of from 1 to 5 feet. It is found growing in canyons of certain of the mountain ranges of northern Mexico and has also been recorded in Texas from Brownsville to Del Rio. In Mexico it grows only in partially protected places, usually near a canyon wall and closely associated with other more robust shrubs which give it protection. It does not thrive in full sunlight. It has quite large, ovate leaves which are rather thickly clothed with short hairs. The flower is bright scarlet. The seed pods are about three-quarters of an inch long and one-half of an inch in diameter. The seeds are naked. The species is well adapted to semi-desert conditions. When dry weather sets in, the plant becomes dormant

[1]Determinations kindly made by Carl Heinrich, Taxonomic Investigations. U. S. Bureau of Entomology, Washington, D. C.

but retains its leaves, many of which revive as soon as moisture is available. Blooming and fruiting are dependent upon moisture conditions. Growth starts immediately when moisture is supplied and usually within two weeks or less buds are developed which produce blooms in from a week to ten days. The blooms last but one day and mature seed pods are produced in from two to four weeks. Maturity seems to be hastened by dry weather.

The eggs of the pink bollworm are deposited on the green pods. The first instar larvae bore into the pod and feed upon the seeds. When the larva becomes mature it either cuts an exit hole in the pod and drops to the soil to pupate, or usually, several seeds may be webbed together to form a cell within which the larva transforms into the pupal stage. Escape of the moth from the pod is easily effected since the latter bursts open upon becoming mature. The green pods are coated with a resinous liquid which is more abundant near the base. This secretion is a natural protection against the pink bollworm. Many of the first instar larvae become caught in it and die before they can gain ingress into the pod.

FIELD RECORDS.—Pink bollworm infestation in seed capsules of this plant in its natural habitat is quite common in the Campana Mountains near Tlahualilo. Examinations of seed pods taken from plants growing in the canyons have been made from time to time during the growing season, during a three-year period, and the results are shown in Table 1. The infestation ranged from nil to 12.28 per cent.

TABLE 1. RESULTS OF EXAMINATIONS OF *H. cardiophyllus* SEED PODS TO DETERMINE PINK BOLLWORM INFESTATION, CAMPANA MOUNTAINS, DURANGO, MEXICO

Date of collection	Number of pods examined	Number of pods infested	Per cent of infestation
August 17, 1929	18	2	11.11
August 21, 1929	22	1	4.54
June 19, 1930	40	3	7.50
April 22, 1931	118	0	0.00
April 29, 1931	93	0	0.00
July 22, 1931	110	2	1.82
October 1, 1931	171	21	12.28

Field examinations also showed that the pink bollworm could pass the winter successfully in seed capsules of this plant. Seed pods from the growing season of 1928, that had remained on the plants in the mountains, were examined at different dates during the spring and summer of 1929. The first trip of the season to the mountains was made May 11, 1929. The region visited was very dry and all plants were showing very few signs of new growth. One live pink bollworm was found webbed up in a section of a pod. This larva was brought to the laboratory where it pupated and the moth emerged. Several more

collections were made at different later dates, and in all, four larvae and one pupa were found. The latest live stage was found July 10.

CAGE TESTS.—Cage tests also proved that the pink bollworm could overwinter in seed pods of *H. cardiophyllus*. Seed pods of this plant were collected in the canyons of the Campana Mountains during November and December of 1928 and were placed in a large emergence cage at Tlahualilo. Moth emergence traps were installed on this cage May 29, 1929. A total of 18 moths emerged from this cage during the summer. Another cage of the same type and using material collected at the same time was installed in the canyon where the plants were growing. A single moth was recovered from this cage. The only differences were that the cage at Tlahualilo was situated some 500 feet lower than the one in the canyon and it was in a plot which was accidentally irrigated during the winter. It is quite possible that the heavier emergence at Tlahualilo was due to the additional moisture, since the winter and spring of that year were very dry. It has been impossible to repeat this test because of the scarcity of seed pods during the past two seasons.

Further cage tests also showed that it is possible for the pink bollworm to perpetuate itself on this malvaceous plant in the absence of cotton. During the fall of 1929 several cages were set up over seed pods that had been collected in the mountains. In the spring cotton was planted in half of these cages and *H. cardiophyllus* plants were placed in the others. None of the cotton plants became infested but a single pod of one of the Hibiscus plants became infested. The tests were repeated in 1930–31 with negative results. These tests can not be taken as conclusive because of the limited amount of material that was available for the cage installations, but it appears that it is possible for the pink bollworm to perpetuate itself on *H. cardiophyllus* under controlled cage conditions provided this plant fruits at the proper time.

It was also proved experimentally that the pink bollworm could transfer readily from cotton to *Hibiscus cardiophyllus*. Early in August, 1930, about 100 pink bollworm moths were introduced into each of two cages covered with 18-mesh screen. Two Hibiscus plants were growing in each cage. All pods on these plants had been examined to insure that the control was effective and that no infestation existed. September 11, 49 pods were examined from the plants in the two cages, and 16 pods or 32.6 per cent, were found to be infested. The infested pods contained from one to three larvae each. All pods had dead first instar larvae on the outside, which shows that the moths oviposit readily on this plant, but that the secretion on the pods acts as a protection against the pink bollworm.

A test was also made to determine if the pink bollworm could transfer from *H. cardiophyllus* to cotton. June 14, 1929, four cotton plants were transplanted to pots from a field at Zaragoza, one of the ranches at Tlahualilo. All of the squares were removed from the plants shortly after transplanting and they were placed in the house where no moths had access to them. At the end of the first week all squares were again removed and this was repeated at the end of the second week. This was done to avoid the possibility of the plants carrying an infestation of pink bollworm with them. June 29, the two surviving plants were again transplanted in a sheltered place in a canyon on the west side of the Campana Mountains. This canyon is about 20 miles from Tlahualilo and about 8 miles air line from the nearest cotton, which was on the east side of the mountain range. In this canyon there were many *H. cardiophyllus* plants, all of which were in a dormant state due to the lack of moisture. Twice each week thereafter the cotton plants were watered. They grew well from the start. July 25, a light rain fell in the canyon and as a result the *H. cardiophyllus* plants began to put out new growth and buds were formed on plants in especially favorable locations. July 31, there were eight squares and three very small bolls on the cotton plants. August 17, three bolls from the cotton plants were examined and all were found infested with pink bollworms. Eighteen green seed pods of *H. cardiophyllus* were examined at the same time; five of these had dead first instar larvae caught in the sticky liquid near the base of the pod and two others each contained a first instar larva. Bolls, squares and blooms

TABLE 2. RESULTS OF EXAMINATIONS OF FORMS FROM TRANSPLANTED COTTON PLANTS GROWN IN A CANYON IN THE CAMPANA MOUNTAINS, DURANGO, MEXICO, FOR PRESENCE OF PINK BOLLWORM

Date 1929	Number and type of cotton forms examined	Number of forms infested	Number and stage of larvae found
August 17	3 bolls	3	1 first instar larva 4 second instar larvae 1 fourth instar larva
August 21	5 dry blooms	2	2 fourth instar larvae
August 24	2 white blooms	1	1 fourth instar larva
August 28	1 boll	1	3 second instar larvae 1 third instar larva
September 14	5 bolls	5	24 second instar larvae

of the cotton plants were examined from time to time at later dates and found infested (Table 2). While this test is in no way conclusive, yet

the indications are that these infestations occurred directly from *H. cardiophyllus* to cotton, as there was no indication of migration from the cotton fields prior to about the last week in August, which was too late a date to account for all of the infestation in the bolls and squares on these cotton plants.

LABORATORY TESTS.—Laboratory tests also showed that the pink bollworm could pass through its life cycle in seed capsules of *H. cardiophyllus*. In these tests, individual seed pods were used on potted plants within a screened room. Moths were confined in small cellophane bags covering individual seed capsules. Also, in other tests, eggs or first instar larvae were placed on the pods which were likewise covered with the cellophane bags. These bags were perforated by numerous very small needle holes to supply air to the pod and to the insects. Two hundred and forty-four of these tests were made with single H. *cardiophyllus* seed capsules, of which 88, or 36.06 per cent, became infested.

Hibiscus coulteri GRAY

This is a low-growing, much branched, perennial shrub seldom attaining a height of more than 2½ feet. The upper leaves are three-parted with lanceolate divisions, the middle one being much the longest. The lower leaves are more ovate with serrated edges. The leaves and green stems are clothed with white hairs which give the plant a silvery appearance. The flowers are yellow with a reddish-brown center. The seed pods are about five-eighths of an inch in length and about five-sixteenths of an inch in diameter. The seeds are clothed with cotton-like fibers, one quarter of an inch long. It is found growing on certain of the mountains of northern Mexico, occurring on top of or near the top of high rocky mesas. In Texas it has been recorded from Del Rio west to New Mexico. The plants grow in the open and thrive best in full sunlight. As is the case with all desert plants, blooming and fruiting are dependent upon moisture conditions.

When pink bollworm infestation occurs, the eggs are deposited on the pods and the first instar larvae bore into the pod and feed upon the seeds. The mature larva usually cuts through the pod wall and drops to the soil to pupate. Sometimes cells are constructed in the pods, by webbing together the seeds, and pupation occurs in these.

FIELD RECORDS.—Seed pods of this plant collected from the Tlahualilo mountains failed to show any pink bollworm infestation. A great many pods were infested by the cotton square borer, *Strymon melinus* Hübn. In one instance an infested seed pod was found on this plant where it was growing in a garden with *H. cardiophyllus*, *H. coulteri* and

cotton. No infestation was found in seed capsules on either of the other species of Hibiscus or in bolls or squares on the cotton plants.

LABORATORY TESTS.—This species of plant was infested quite readily under experimental conditions as the following described tests indicate. The same methods of transfer to individual seed capsules on potted plants in the insectary were used as described for *H. cardiophyllus*. Moths were confined with 7 pods but no infestation was obtained. First instar larvae or eggs were transferred to 62 pods, 44 of which became infested. The total average infestation, including the tests where moths were used, was therefore 63.7 per cent. Moths reared from the infested *H. coulteri* pods oviposited when confined on seedling cotton plants. In one case when these eggs were transferred to cotton bolls, infestation in cotton was produced.

Hibiscus denudatus GRAY

This plant is a low-growing perennial seldom attaining a height of more than 2 feet. In winter it dies back to a stump which sends out numerous, sparsely leaved stems in the spring. The small, ovate leaves, and also the stems, are thickly clothed with fine, short, white hairs which give the plant a greyish appearance. The blooms are light purplish blue with a red center. The seed pods are about five-eighths of an inch in length and about five-sixteenths of an inch in diameter. The seeds are clothed with cotton-like fibers about one-quarter inch in length. The plant is found growing on top of low, rocky hills in northern Mexico. In Texas it is recorded west of Pecos. It occurs in the open and thrives best in full sunlight.

FIELD RECORDS.—Examination of seed pods of this plant collected in the mountains failed to show any infestation by the pink bollworm.

LABORATORY TESTS.—Transfers to individual seed capsules were made using the same method as described for the *H. cardiophyllus*. Ninety-six transfers were made, of which only 15, or 15.6 per cent, were successful. Some of the larvae had a stunted appearance, although perfectly normal-appearing moths were obtained from part of these larvae and in at least one case the moths oviposited on seedling cotton plants. It is doubtful if this species can be considered a favorable host plant.

OKRA (*Hibiscus esculentus* L.)

This cultivated plant is not generally grown in northern Mexico although an occasional small planting is found. When pink bollworm infestation occurs, the young larva bores into the pod and feeds on the

seeds. When mature, it may bore a hole through the pod wall and drop to the soil to pupate or it may form a cell by webbing several seeds together and pupate within this. A majority of the long-cycle larvae construct similar cells in the pods, although some leave the pods and form hibernation cells elsewhere.

FIELD RECORDS.—Okra becomes infested by the pink bollworm quite readily. It is not uncommon to encounter infestations as high as 50 or 60 per cent.

CAGE TESTS.—Hibernation cage tests were conducted during the winters of 1928–29, 1929–30 and 1930–31. The tests that were conducted during the first winter were unavoidably interrupted and as a result the records are incomplete, but sufficient data were obtained to show that there was a large overwintering survival of the pink bollworm in okra that year. The results of the tests from 1929 to 1931 are shown in Table 3. An examination of the data shows that the pink bollworm can winter in okra pods at Tlahualilo. The data also show that when the okra pods have both added protection and moisture at the proper time, the survival is much greater.

TABLE 3. SURVIVAL OF PINK BOLLWORM IN OKRA PODS, TLAHULILO, DURANGO, MEXICO, 1929–1931

Treatment	Per cent Survival		
	1929–30	1930–31	Average
Pods on stalks, no irrigation	0.94	1.0	0.97
Pods buried 2 inches, no irrigation	4.72	7.0	5.86
Pods buried 2 inches, irrigated in March	18.87	31.0	24.935
Pods not buried, no irrigation	3.77	11.0	7.385
Pods not buried, irrigated in March	4.72	6.0	5.36

HOLLYHOCK (*Althaea rosea* L.)

Hollyhock is quite generally grown in northern Mexico as an ornamental. The plants come up early in the spring and bloom and die down after setting a seed crop. Usually the plants are cut down soon after the blooming season, as they become very unsightly. When pink bollworm infestation occurs, the young larva bores into the seed pod and feeds on the seeds until mature, whereupon it may pupate in the pod or drop to the soil. When pupation occurs in the pod, no pupal cell is formed.

FIELD RECORDS.—An examination of 1000 seed pods of hollyhock in June, 1931, showed that 7 of them were infested by the pink bollworm. Previous to this examination an occasional infested pod had been noted but no attempt had been made to determine the actual percentage of infestation. Several of these larvae were reared to the adult stage and the determination as pink bollworm verified.

It is not likely that hollyhock will ever become a serious factor in pink bollworm infestation because of the fact that the growing season of the plant comprises such a small part of the year. Furthermore, its season of fruiting is so early that it is very doubtful if larvae developing in its seed capsules would ever enter the long-cycle phase.

Summary

1. The plants studied at Tlahualilo and found capable of being host plants to the pink bollworm were: *Hibiscus cardiophyllus*, *Hibiscus coulteri*, *Hibiscus denudatus*, *Hibiscus esculentus* (okra), and *Althaea rosea* (hollyhock).

2. *H. cardiophyllus* was found quite commonly infested with pink bollworms in its native habitat and was found to be capable of sustaining the pink bollworm from year to year if given favorable moisture conditions.

3. *H. coulteri*, while not found infested in its native habitat, is a possible potential host plant of the pink bollworm. It becomes infested readily when exposed to the pink bollworm under laboratory conditions.

4. *H. denudatus*, although infested by the pink bollworm in the laboratory, was less easily infested under these conditions than the other two mentioned hibiscus plants. It was not found infested in its native habitat.

5. Okra is a favorable host plant but is of little importance in northern Mexico because of the limited plantings.

6. Hollyhock is a host plant on which the pink bollworm may pass its life cycle but it is of little importance because of seasonal habit.

EIGHT YEARS OF EXPERIMENTAL WORK IN BOLL WEEVIL CONTROL ON PLOTS RECEIVING DIFFERENT RATES OF FERTILIZER

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Abstract

Calcium arsenate controlled the boll weevil (*Anthonomus grandis* Boh.) on one-twentieth-acre plots over an eight-year period. Infestation counts were made bi-weekly and calcium arsenate was applied when the infestation reached or exceeded ten per cent. All applications were made during the day time when the air was relatively calm.

Eight years of study in boll weevil control with calcium arsenate have been completed at the Alabama station. The writers (1926 and 1929) published results obtained on three types of soils during the first five years of the tests. This paper contains data obtained in an eight-year experiment at Auburn on Norfolk sandy loam soil receiving various amounts of fertilizer.

Experimental Methods

Arrangement of Plots. Two tiers of experimental plots were used in the studies, each tier consisting of seven one-twentieth-acre plots. Plots 1, 4, and 7 in each tier were unfertilized, whereas plots 2, 3, 5, and 6 received annually 500, 1000, 1500, and 2000 pounds of fertilizer respectively, per acre. This fertilizer was mixed in the following proportions: 300 pounds superphosphate, 150 pounds nitrate of soda, and 50 pounds muriate of potash. The two tiers of plots were separated by a thirty-foot alley-way which was dusted but not fertilized. This dusted alley-way was provided to prevent the spread of the boll weevil from undusted to dusted plots; O'Kelley and Cowart (1923) had previously found that six rows of dusted cotton provided a sufficient barrier. One tier of plots and the alley-way were dusted when the infestation reached 10 per cent, whereas the other tier was not dusted. The dusted tier of plots was alternated annually with the undusted, so as to neutralize any effect of differences in soil fertility.

Determining the Infestation. The infestation was determined by counting the number of squares punctured among 100 examined on each of the fourteen plots at regular intervals throughout the fruiting season. Fifty squares were examined a short distance from each end of a plot, the number containing infestation punctures was recorded, and the average per cent infestation for a tier calculated. These counts have been made twice a week since 1926; previous to that time they were made once or twice a week. In determining infestation, cotton plants were selected at random and all squares on a plant were examined before counting was begun on a new one.

Applying the Dust. Dusting with calcium arsenate was begun when the average infestation reached 10 per cent or above. Three applications were then made at intervals of four to six days, since the work of Coad (1918) and Coad and Cassidy (1921) had shown such a procedure to be effective.

Following the first series of dustings, other applications of calcium arsenate were made when the infestation approached 20 per cent. These applications were not necessarily made in a series of three dustings, but

were made only when considered necessary to prevent the infestation from exceeding 20 per cent. This method of dusting was continued throughout the fruiting period of the cotton. In a few instances one application of dust was made to protect the young bolls after the setting of fruit had ceased.

Calcium arsenate was applied with a mule-drawn two-row dust gun, at the rate of approximately seven pounds per acre. Applications were made at any time of day, ranging from early morning to evening, but at a time when the air was relatively calm. No dustings were made at night. The condition of the cotton foliage varied from wet to dry. Applications of dust were repeated if a heavy rainfall occurred within twenty-four hours after dusting.

Infestation and Dusting Data

Dusting to protect the cotton against boll weevil injury during the fruiting period was necessary during five of the eight years the tests were conducted, namely, 1924, 1926, 1927, 1928, and 1929. During the other three years, 1925, 1930, and 1931, the boll weevil was not present in sufficient numbers to warrant dusting.

The Five-Year Period. Heavy boll weevil infestation occurred much earlier some years than others, the date of the first 10 per cent infestation record on the dusted plots varying from June 13, in 1927, to August 27, in 1926 (Table 1). The infestation first reached 10 per cent August 12 in 1924, and August 10 in both 1928 and 1929. The number of dustings also varied from year to year. In 1927, when the infestation exceeded 10 per cent June 13, a total of eleven dustings were required, while in 1926, when the infestation did not reach 10 per cent until August 27, only three dustings were required. The average number of dustings per year was 5.2 for the five-year period.

Dusting with calcium arsenate materially reduced the percentage of infestation, provided the cotton was fruiting freely at the time the dust was applied. A study of Table 1 will show that the infestation decreased on the dusted plots following each series of dusting, while it usually increased on the undusted plots during the same periods. This difference in infestation indicated that the cotton was being protected from boll weevil injury.

The Three-Year Period. The infestation did not reach 10 per cent during the fruiting season of 1925, 1930, or 1931. Dusting for protection against the boll weevil was, therefore, not necessary.

TABLE 1. PER CENT INFESTATION, OVER A FIVE-YEAR PERIOD WHEN DUSTING FOR PROTECTION FROM BOLL WEEVIL DAMAGE WAS NECESSARY DURING THE GROWING SEASON

	1924		1926		1927		1928		1929	
	% Infestation		% Infestation		% Infestation		% Infestation		% Infestation	
Date	Undusted	Dusted	Undusted	Dusted	Undusted	Dusted	Undusted	Dusted	Undusted	Dusted
June 9..	—	—	—	—	11.2	0.0	—	—	—	—
June 13..	—	—	—	—	7.0	20.5	—	—	—	—
June 14..	—	—	—	—	—	X*	—	—	—	—
June 16..	—	—	—	—	—	X	—	—	—	—
June 20..	—	—	—	—	9.5	15.5	—	—	—	—
June 21..	—	—	—	—	—	X*	—	—	—	—
June 22..	—	—	—	—	—	X*	—	—	—	—
June 23..	—	—	—	—	—	X	—	—	—	—
June 27..	—	—	—	—	—	X	—	—	—	—
June 28..	—	—	—	—	23.4	8.4	—	—	—	—
July 1..	—	—	—	—	35.8	4.1	—	—	—	—
July 2..	—	—	—	—	—	—	—	—	8.0	0.0
July 5..	—	—	—	—	35.3	2.4	—	—	8.4	0.0
July 6..	—	—	1.0	0.0	—	—	—	—	—	—
July 8..	—	—	—	—	41.2	2.5	—	—	—	—
July 9..	—	—	—	—	—	—	—	—	0.8	0.0
July 11..	—	—	—	—	—	—	.60	1.00	—	—
July 12..	—	—	—	—	51.0	5.4	—	—	0.8	0.0
July 13..	—	—	0.0	0.0	—	—	—	—	—	—
July 15..	—	—	—	—	43.2	16.7X	—	—	—	—
July 16..	—	—	—	—	—	—	—	—	0.6	0.0
July 17..	—	—	—	—	—	—	3.70	2.20	—	—
July 19..	—	—	—	—	45.2	16.7X	—	—	0.0	0.2
July 20..	—	—	—	—	—	—	2.20	.40	—	—
July 21..	—	—	0.0	0.5	—	—	—	—	—	—
July 22..	—	—	—	—	56.9	12.9	—	—	3.8	0.0
July 24..	—	—	—	—	77.4	9.6	.50	.50	0.6	0.4
July 27..	—	—	—	—	—	X	.70	.50	—	—
July 29..	—	—	—	—	86.3	13.8	—	—	—	—
July 30..	—	—	—	—	—	X	—	—	2.0	1.0
July 31..	—	—	—	—	—	—	.25	4.00	—	—
Aug. 2..	—	—	—	—	90.3	17.0	—	—	5.0	1.6
Aug. 3..	—	—	—	—	—	—	.75	3.25	—	—
Aug. 6..	0.0	4.7	—	—	87.4	83.4	—	—	8.0	1.2
Aug. 7..	—	—	—	—	—	X	1.25	3.00	—	—
Aug. 9..	—	—	—	—	95.7	80.5	—	—	—	—
Aug. 10..	—	—	—	—	—	—	2.80	10.50	16.2	11.6
Aug. 12..	12.2	10.2X	0.0	0.0	92.5	86.0	—	X	—	X*
Aug. 13..	—	—	—	—	—	—	—	—	18.0	21.9X
Aug. 14..	—	—	—	—	—	—	3.30	6.70	—	—
Aug. 16..	25.7	43.5X	—	—	93.1	91.2	—	X*	26.6	17.4X
Aug. 18..	—	—	—	—	—	—	1.71	3.10X	—	—
Aug. 20..	43.0	16.0	—	—	—	—	4.00	1.70	49.0	6.4
Aug. 21..	—	X	—	—	—	—	—	—	—	—
Aug. 23..	—	—	4.0	4.0	—	—	—	—	41.0	2.6
Aug. 27..	—	—	15.3	13.0	—	—	22.60	2.40	57.8	1.5
Aug. 28..	74.0	58.5	—	X	—	—	—	—	—	—
Aug. 30..	—	X	—	—	—	—	—	—	84.9	9.2
Aug. 31..	—	—	27.8	12.3	—	—	64.30	4.40	—	X
Sept. 3..	—	X	59.1	17.7X	—	—	—	—	95.0	18.0X
Sept. 7..	—	—	—	X	—	—	70.00	20.60	—	—
Sept. 14.	—	—	57.7	20.7	—	—	—	—	—	—

X—Date Dusted. *—Heavy Rain Within 24 Hours.

Yields of Seed Cotton

The Five-Year Period. The yields of seed cotton on the various plots, during the five years that protection against the boll weevil was necessary, are given in Table 2. The gain from dusting the unfertilized cotton was almost negligible. On the cotton receiving 500 pounds of fertilizer per acre, the gain from dusting varied from 46 pounds in 1929 to 561 pounds in 1927, with a five-year average gain of 246 pounds of seed cotton per acre. On the plots receiving 1000 pounds of fertilizer per acre, the gain from dusting varied from 134 pounds in 1929 to 739 pounds in 1927, with a five-year average gain of 409 pounds of seed cotton per acre. The five-year average gains on the plots receiving 1500 and 2000 pounds of fertilizer per acre were 396 and 365 pounds, respectively.

Table 2. Yields of Seed Cotton on Dusted and Undusted Plots Over a Five-Year Period When Protection From Boll Weevil Damage was Necessary

Fertilizer per Acre	Treatment	Pounds of Seed Cotton per Acre						
		1924	1926	1927	1928	1929	Average	Gain
0	Dusted	186	176	360	72	82	175.2	
	Undusted	84	164	129	84	86	109.4	65.8
500	Dusted	678	688	843	451	628	657.6	
	Undusted	456	484	282	256	582	412.0	245.6
1000	Dusted	1050	1294	1212	1064	1138	1151.6	
	Undusted	756	912	473	570	1004	743.0	408.6
0	Dusted	94	168	275	38	62	127.4	
	Undusted	102	138	51	56	28	75.0	52.4
1500	Dusted	1352	1680	1468	1050	1230	1356.0	
	Undusted	1148	1260	606	710	1078	960.4	395.6
2000	Dusted	1402	1898	1496	1308	1238	1468.4	
	Undusted	1304	1414	565	1166	1068	1103.4	365.0
0	Dusted	24	52	260	8	120	92.8	
	Undusted	136	132	43	62	12	77.0	15.8

It is interesting to note that the greatest gains occurred in 1927 (Table 2) when a high infestation occurred early and was continuous throughout the season (Table 1). The gains were less during the years that later and lower infestations occurred. Other factors entered into the situation, however. One of these was the state of maturity of the cotton plants and the rate of fruiting at the time the infestation occurred, irrespective of the date. This factor was, in fact, more important than the actual time of year. Another factor was the productivity of the cotton from year to year. Since calcium arsenate only

protects cotton after the plants have produced it, there was a tendency for greater gains when the yields were high (Table 2), provided the infestations were also high (Table 1) and the cotton was fruiting freely at the time of the dustings.

THE THREE-YEAR PERIOD. Since boll weevil damage was not a factor in 1925, 1930, and 1931, a study of the average yields during these three years will serve to indicate the effect of climatic conditions and soil variations. In arriving at the average yields, a scheme of annually alternating northern and southern tiers was followed, as was done in the dusting tests. That is, the yields of plots which normally would have been dusted, had the boll weevil been sufficiently numerous, are contrasted with their corresponding control plots.

Relatively small differences occurred in the yields of the various comparable plots. The average difference varied from 2 to 50 pounds of seed cotton per acre on the unfertilized plots (Table 3). On the fertilized plots the average per acre differences were 12, 2, 51, and 54 pounds, respectively, for plots receiving 500, 1000, 1500, and 2000 pounds of fertilizer.

TABLE 3. AVERAGE YIELDS OF SEED COTTON OVER A FIVE-YEAR PERIOD WHEN PROTECTION FROM BOLL WEEVIL DAMAGE WAS NECESSARY CONTRASTED WITH A THREE-YEAR PERIOD WHEN PROTECTION WAS NOT NECESSARY

		Pounds of Seed Cotton per Acre				
		Five-Year Average (1924–26–27–28–29)			Three-Year Average (1925, 1930, 1931)	
Fertilizer per Acre	Treatment	Yield	Gain	Treatment	Yield	Difference
0	Dusted	175.2		Undusted	341.6	
	Undusted	109.4	65.8	Undusted	345.6	4.0
500	Dusted	657.0		Undusted	893.6	
	Undusted	412.0	245.6	Undusted	881.6	12.0
1000	Dusted	1151.6		Undusted	1287.0	
	Undusted	743.0	408.6	Undusted	1289.0	2.0
0	Dusted	107.4		Undusted	284.6	
	Undusted	75.0	32.4	Undusted	311.0	26.4
1500	Dusted	1344.4		Undusted	1404.3	
	Undusted	950.4	394.0	Undusted	1455.6	51.3
2000	Dusted	1459.6		Undusted	1315.6	
	Undusted	1095.2	364.4	Undusted	1370.0	54.4
0	Dusted	92.8		Undusted	215.3	
	Undusted	77.0	15.8	Undusted	265.0	49.7

CONTRAST OF THE FIVE- AND THREE-YEAR PERIOD. A summary of the average yields over the five-year period as contrasted with the three-year period is given in Table 3. It is obvious that the differences of 12

pounds and 2 pounds, respectively, on the 500 and 1000 pounds of fertilizer plots are small and insignificant when compared with 246 and 409 pounds per acre gain from dusting the same plots. The differences in yield due to factors other than boll weevil control are relatively larger on the plots receiving 1500 and 2000 pounds of fertilizer, but are also obviously insignificant when compared with the gains from dusting the same plots. A statistical analysis would be necessary to determine whether or not significant differences, in favor of dusting, occurred on the unfertilized plots. Since the cost of the dusting operation, however, is such that boll weevil control on nonfertile soil is at best unprofitable, there is no justification for such an analysis.

Cost of the Dusting Operation

The average cost of the dusting operation is difficult to determine as the variations in prices of calcium arsenate, labor, and machinery are rather large from year to year. In figuring the average costs for this report, the price of calcium arsenate was fixed at 9 cents a pound; actually the price varies from about 6 to 12 cents. The price of labor was fixed at 15 cents an hour for a man to operate the dust gun and 15 cents an hour for a mule to pull the gun. The entire price of a dust gun was charged to four years of operation, although some guns have been known to operate five or more years with only minor repairs.

Based on the aforementioned prices, the average annual cost of dusting for the five-year period was $5.03 per acre. This included $3.24 for calcium arsenate, $1.04 for labor to apply the dust and $.75 for depreciation on the dusting machinery. It was assumed in arriving at the charge against depreciation that a $60 two-row dust gun would take care of 20 acres of cotton.

Summary

Experiments in boll weevil control with calcium arsenate were conducted over a period of eight years on twentieth-acre plots receiving different rates of fertilizer. Dusting was necessary during five years of the test and unnecessary during the other three years.

The date of the first 10 per cent infestation varied from June 13, in 1927, to August 27, in 1926. Applications of dust were made at different times of day, varying from early morning to evening, but at a time when the air was relatively calm.

There was little increase in yield from dusting the unfertilized cotton. The average gains from dusting the fertilized cotton were 246, 409, 396, and 365 pounds of seed cotton per acre on the respective plots receiving 500, 1000, 1500, and 2000 pounds of fertilizer.

The number of dustings per season varied from 3 to 11, with an average of 5.2.

The amount of calcium arsenate required per acre each season varied from 21 to 77 pounds, with an average of 36 pounds.

The average annual cost of the dusting operation was approximately $5.00 per acre.

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TECHNIQUE FOR ARTIFICIAL INOCULATIONS OF THE COTTON PLANT

By W. S. Cook, *Assistant Microscopist Cotton Insect Investigations, Bureau of Entomology, Tallulah, La.*

Abstract

A description of the apparatus used in making artificial inoculations is given. A full description of the micro-manipulator and of the making of the capillary glass points is also given. The special technique used in making the inoculations is presented in detail.

The results of previous work carried out on the cotton flea hopper indicated that the effect on the plant is a reaction to irritating or toxic substances injected by the insects when feeding. In order to secure definite proof along this line an inoculation technique had to be worked out by means of which different substances might be artificially injected into the plant; the ultimate aim of the experiments being to duplicate artificially, if possible, the same damage caused by the insects. Results of a few preliminary tests showed that artificial inoculations, without a great deal of mechanical injury, might be made by means of fine capillary glass points handled with a micro-manipulator.

Description of Apparatus Used in Making the Inoculations

The Stand.—This piece of apparatus consists of a heavy rounded cast-iron base to which is fastened a vertical steel rod 52 inches long,

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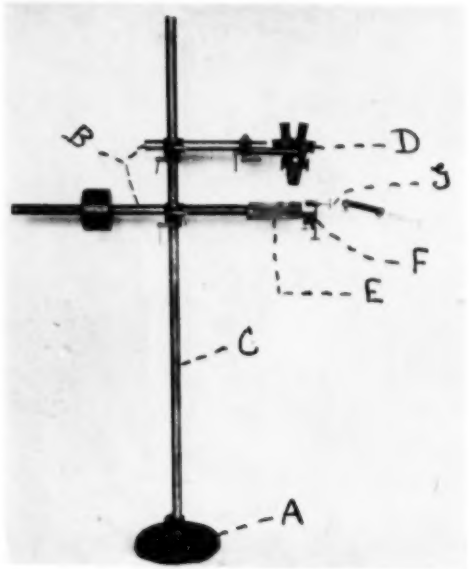

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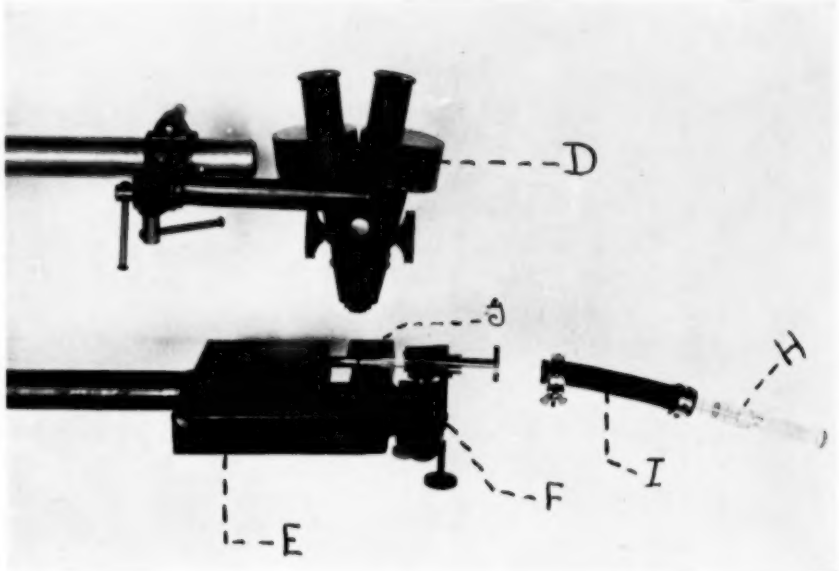

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1. Set-up of the apparatus as used in the field for making artificial inoculations. A. Base. B, upper and lower horizontal rods. C, vertical rod. D, Binocular microscope. E, stage. F, micro-manipulator. G, Capillary glass point.

2. Enlarged view showing part of the apparatus used in making artificial inoculations. D, Binocular microscope. E, stage. F, micro-manipulator. G, Capillary glass point. H, Glass syringe. I, Rubber tubing.

provided with two movable and adjustable clamps. These clamps support and carry two horizontal steel rods. The upper horizontal rod provides means of support for an adjustable clamp which carries the binocular microscope. By means of this clamp the binocular may be aligned in practically any position wanted for observation. The lower horizontal rod carries on one end a flat stage which is merely a flat piece of metal welded to the end of the rod. This stage provides a flat surface for making the inoculations, and also provides a means of support for fastening the micro-manipulator. The other end of the horizontal rod is provided with a movable counter-balance which helps to stabilize the apparatus. Plate 22, figure 1 shows the set-up of the apparatus.

THE MICRO-MANIPULATOR.—This piece of apparatus fastens directly to the stage by means of a set screw and clamp, which are integral parts of the manipulator. The micro-manipulator is provided with three knurled screw heads, which actuate the two horizontal and one vertical screw thrusts. There is also provided on the top horizontal screw thrust a grooved slot in which the capillary glass point is securely held. By rotation of the three screw heads the capillary glass point may be moved in any of the three planes, i. e., one horizontal and two vertical. Movement of the capillary point may be controlled with precision in any of the three directions. The micro-manipulator is a standard piece of apparatus and was purchased from one of the large optical companies.

THE CAPILLARY GLASS POINTS.—The most important parts of the apparatus used in making the artificial inoculations are the capillary glass points. Considerable difficulty has been experienced in making these points, and while a fairly satisfactory method has been worked out, it is felt that much improvement could be made in the method. The following is the method that has been mostly used in making the points. Glass tubing of a 5–6 mm. bore was used. A piece about 10 inches long was heated in the center with a hot Bunsen flame, and a long capillary tube drawn out, which was broken off about 3 inches from the shoulder of each piece. The capillary glass point was then made by holding one end of the capillary tube with a pair of forceps and gently heating in the smallest possible flame from an alcohol lamp. As the capillary tube melted a quick pull with the forceps resulted in a fine point. Glass points should be straight and about one-quarter inch long. Approximate sizes of the different capillary points are as follows: Fine points, 10–25 microns in diameter; medium points, 30–50 microns in diameter; coarse points, 55–100 microns in diameter.

Inoculation Technique

When making field inoculations the following procedure was usually followed: The ground around the plants to be inoculated was leveled so that the apparatus would be stable and stand on an even keel. After placing the apparatus, the lower horizontal rod was adjusted to the height of the plant and the upper rod brought in correct alignment with the lower, so that the part of the plant to be inoculated (either petiole or stem) could be viewed through the binocular. The capillary glass point was then dipped into the inoculating solution, enough being taken up by capillary attraction for the inoculation. After the capillary was filled, the glass point was securely fastened in the micro-manipulator. When making an inoculation the stem or petiole of the plant was held securely on the stage with the left hand, the right hand being used to focus the binocular and operate the micro-manipulator. Great care had to be taken to hold the plant very firmly when the capillary point came in contact with it, because even slight motion of the plant would usually tend to break the capillary point.

One of the greatest difficulties experienced in making the inoculations was to get the liquid to flow from the capillary point into the plant. Occasionally it would flow readily, but most of the time it had to be forced out of the capillary point. Several methods were tried, such as heating the glass tube, using a rubber bulb on the end of the tube, etc., but none proved satisfactory and all were soon discarded. Finally the following method was tried and proved fairly satisfactory. A glass syringe, of a standard make, of 5-cc. capacity was used. On the small end of the syringe was fastened a 5-inch length of rather stiff rubber tubing, the connection being made completely air-tight by means of a small clamp. The other end of the rubber tubing was slipped over the end of the glass tube, this connection also being made completely air-tight by means of a small clamp. The plunger of the syringe was kept well greased with vaseline so that no leakage of air could occur at that point. If the system, as outlined above, was completely air-tight, pushing the plunger in and out would usually create enough air pressure to force the liquid from the capillary point into the plant. Plate 22, figure 2 shows an enlarged view of the micro-manipulator and capillary glass point.

During the making of the inoculation the service of an assistant was necessary to operate the plunger of the syringe. The capillary point was pushed into the plant to the required depth and the liquid watched as it flowed from the capillary into the plant. After the point was withdrawn the place of inoculation was marked with India ink. As a rule three inoculations were made upon each petiole, one of which was a check

inoculation. Daily notes were taken on the inoculations, and at the end of 5 days the material was collected and brought into the laboratory for sectioning.

MIGRATION AND POPULATION STUDIES OF THE COTTON BOLLWORM MOTH (*HELIOTHIS OBSOLETA* FAB.)

By J. C. GAINES, *Texas Agricultural Experiment Station*[1]

ABSTRACT

A cart-type of screen trap, which was pushed along over cotton in the field, proved quite successful in obtaining information regarding the extent of local migration and the abundance of bollworm moths in the fields. Correlating these records with those taken in connection with oviposition, bollworm injury, and rate of plant growth, it was found that oviposition and the rate of plant growth were closely associated, but that there was no relation between the moth population and the oviposition in these fields.

The cotton bollworm (*Heliothis obsoleta* Fab.), one of the oldest cotton pests, causes a much greater loss to the cotton planters than is commonly suspected. The methods for combating this insect, as recommended up to the present time, have not been generally accepted. The planters have not accepted the recommended control measures because of the "spotted" infestations that occur and the difficulty in knowing when to make applications for the best control. Corn is usually heavily infested with Heliothis every year, but only spotted infestations generally occur in the cotton. Apparently there is at least a local migration of moths, and a knowledge of the migratory habits and information regarding the population of the moths in some cotton fields have been found important in understanding the problem of combating this insect.

Since very little information is available on this subject, and since the moths seem to be peculiarly selective when ovipositing, it was deemed advisable to conduct experiments to show, if possible, the causes that influence migration. As corn seems to be the source of moths that cause infestations in cotton, a series of traps (Plate 23) was used to determine if there was a movement of moths from corn to cotton or between different cotton fields. In 1930 and 1931, three different types of screen traps, covered with a sticky tree-banding preparation, were located in various cotton fields, some in close proximity to, and others at considerable distances from cornfields. Daily visits were made to these traps during the migratory period of the moths. No moths were caught on any of these traps, although moths were observed flying in the various fields in fairly

[1]In cooperation with the Bureau of Entomology, U. S. Department of Agriculture.

large numbers, and a heavy oviposition on tomatoes, scattered throughout some of the cotton fields, showed that the moths were abundant. However, the infestation in the cotton was low, less than one per cent of the forms being injured.

One type of trap used was horizontal and roof-like and was designed to take advantage of a habit of the moths to fly upward. It was placed over several cotton plants, which were sprayed with a syrup solution to attract moths. This trap likewise proved unsuccessful.

A two-wheel cart type of trap (Plate 24) was then constructed for running over two rows of cotton at a time. The framework of this trap was 8 feet long, covered with screen wire, and mounted on two bicycle wheels. This was pushed along the rows by man power, the man being behind so as not to disturb the moths before the trap was over them as they flew up. This was based on Bishopp's[2] idea and proved very successful in obtaining information on the migration and on the abundance of the population of moths in various fields.

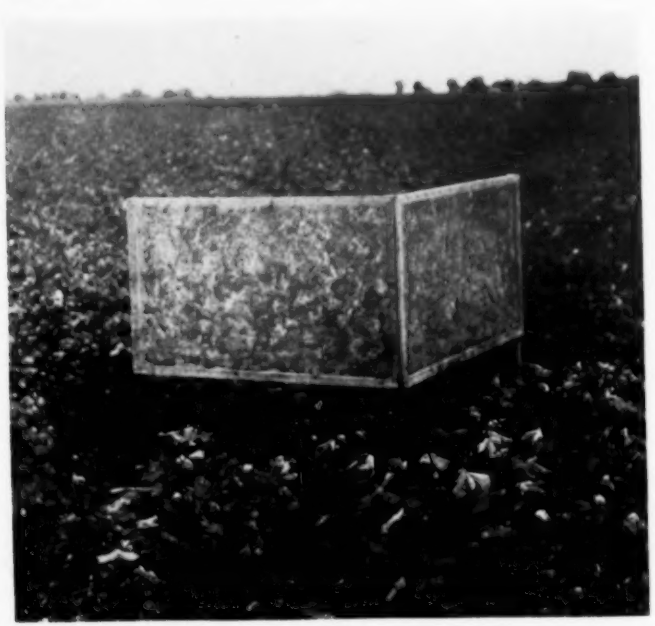
During the period July 28 to September 9, 1,125 moths were captured in this cart trap from two different fields. In one field, 312 moths were caught and released on ten different days and were marked in such a manner that the date of release would be known if the moths were recaptured. Moth collections were made about every three days in the same field and at distances of 150 and 280 yards and one mile from the point of release. With the exception of one instance, in which a moth had a broken wing, none of the marked moths were recaptured. Only 72 of the 312 moths, or 23 per cent, were released during the period when the cotton was making its most rapid growth.

In the latter portion of the collecting period, determinations showed that the sexes were about equally divided, the male moths being slightly in the majority. This proportion also occurred among adults that were reared from larvae collected from a millo maize field in the vicinity and indicated that the cart trap was capturing a typical sample of the population.

In order to determine the number of moths per acre and their relation to the infestation, this cart trap was pushed over two and one-half acres of rank and of small cotton about twice a week, and the catch was recorded. This work continued for 51 days, or a period of time during which the first and second generations of moths in cotton would be flying. It so happened that after three weeks, or about the middle of this period, both the rank and the small cotton ceased to make much,

[2]Bishopp, F. C., "A Unique Insect Catching Machine." Jour. Econ. Ent., 3:314, 1910.

Plate 23



Type of traps used in studies of the migration of cotton bollworm moths.

The cart type of trap used to catch cotton bollworm moths.

if any, increase in growth. The number of eggs per acre, forms injured, and average plant growth were also recorded throughout this period and are presented in Table 1.

TABLE 1. RECORDS OF COTTON BOLLWORM MOTHS, EGGS, AND NUMBER OF INJURED FORMS PER ACRE IN RANK AND IN SMALL COTTON DURING A RAPIDLY-GROWING PERIOD AS COMPARED WITH A SLOWLY-GROWING PERIOD

Dates	Average catch number moths per acre		Average number eggs per acre		Average number injured forms per acre		Average plant growth in inches	
	Rank	Small	Rank	Small	Rank	Small	Rank	Small
1st period 21 days July 22 to Aug. 11	21	48	888	796	4,571	1,193	6.47	5.73
2nd period 27 days Aug. 14 to Sept. 9	65	43	109	40	2,638	2,385	0.71	1.57
Entire season.....	44	45	508	355	3,411	1,908	7.18	7.30

It is obvious from the data that there is no significant correlation between moth population and the number of eggs per acre. But there is a very significant correlation between the number of eggs per acre and the rate of growth of cotton in the first period as compared with the number of eggs and the rate of growth in the second period. The greatest oviposition occurred during the first period when the cotton was growing rapidly, and the significance of this occurrence is further emphasized by the fact that there were about twice as many moths to lay eggs during the second as in the first period. This was probably due to the moths drifting in greater numbers from field to field in search of a desirable place for oviposition after the cotton had ceased growing.

In the first part of the season, during the 21 days from July 22 to August 11, inclusive, less than one-half the number of moths in the rank cotton produced about 10 per cent more eggs and four times as many injured forms as the larger number of moths produced in the small cotton. Even though the rank and small cotton grew in height at about the same rate, there was a big difference in the amount of foliage on the cotton in the two fields. The plants in the field designated rank cotton were about 12 inches higher than the plants in the field designated small cotton, and the plants of the former put on much more succulent limb growth than the latter. This condition in the rank cotton probably afforded a much better place for insect development than in the small cotton. In the latter part of the season, during the 27 days from August 14 to September 9, inclusive, 50 per cent more moths in the rank cotton than were in the small cotton produced more than twice as many eggs, but only about 10 per cent more injured forms. As the cotton had about attained its maximum growth prior to this period in both fields, it was

apparently less attractive to the moths for oviposition. The rank cotton continued to be attractive for oviposition longer than the small cotton, but the worms did not develop and cause much injury, probably because of control by natural enemies.

OBSERVATIONS ON A COMBINED BOLL WEEVIL AND PINK BOLLWORM INFESTATION IN NORTHERN MEXICO

By C. S. RUDE, *Assistant Entomologist, Bureau of Entomology* and CHARLES L. SMITH, *Field Assistant, Bureau of Entomology*

ABSTRACT

A combined heavy boll weevil (*Anthonomus grandis* Boh.) and pink bollworm (*Pectinophora gossypiella* Saund.) infestation occurred in cotton at Tlahualilo, Durango, Mexico, in 1931. Weekly records were made on the percentage of both square and boll infestations caused by these two species. It was found that the multiplication and development of neither species was checked by that of the other.

During the growing season of 1931 an unusually heavy boll weevil infestation was discovered in cotton at Tlahualilo, in the State of Durango, Mexico. An opportunity was thus presented to observe under field conditions the effect of this boll weevil infestation upon that caused by the pink bollworm, since the latter species was also present in the cotton fields in large numbers. The question has been asked as to what damage the pink bollworm could cause should it ever spread to the eastern part of the cotton belt of the United States where a heavy boll weevil infestation is often found. The three possibilities are as follows: (a) the presence of the boll weevil in large numbers would retard the development and multiplication of the pink bollworm; (b) the pink bollworm would similarly affect the boll weevil; (c) neither species would be affected by the other. The following paper is a discussion of this combined heavy boll weevil and pink bollworm infestation.

The records of boll weevil infestation discussed herein are based upon the actual occurrence of either the egg or the larva of this insect in the squares and bolls. No weevil feeding punctures were considered. The percentages of boll weevil infestation therefore can not be considered as comparable with those as usually recorded for the cotton belt of the United States. The data on pink bollworm infestation are based on the occurrence of the larva only in the squares and bolls.

To determine infestation percentages, collections of squares and bolls were made weekly in four cotton fields on the Tlahualilo property. Samples were taken from five points in each field as follows: one in each corner and one in the center. Twenty bolls and one hundred squares

were picked from each of these points. Thus 100 bolls and 500 squares were collected from each field every week.

BOLL WEEVIL INFESTATION. The seasonal trend of the percentage of boll weevil infestation was not constant, but high and low points were observed. (Tables 1 and 2 and Fig. 41.) These fluctuations in the percentage curves may have been the result of similar fluctuations in

TABLE 1. AVERAGE INFESTATION IN SQUARES BY THE BOLL WEEVIL AND THE PINK BOLLWORM, TLAHUALILO, DURANGO, MEXICO, 1931

Date 1931	Squares infested by boll weevil *Per cent*	Squares infested by pink bollworm *Per cent*
July 13	1.85	0.75
July 20	1.33	0.47
July 27	2.55	0.95
August 3	8.45	1.45
August 10	14.9	2.00
August 17	15.5	8.3
August 24	20.3	16.0
August 31	23.5	23.8
September 7	28.6	28.4
September 14	31.9	34.9
September 21	29.3	41.0
September 28	20.7	54.4
October 5	19.9	51.5
October 12	24.0	50.4
October 19	21.0	46.6
October 26	28.1	39.9

the fruiting of the cotton plants; they may have been due to the fact that a generation of the boll weevil had reached its height of development or was at the low point in this regard, or they may have been due to a combination of both factors. Since the number of squares per plant was not determined, the influence of this factor can not be estimated. The average number of bolls per plant was noted, however, and no perceptible change was noted in the percentage of bolls infested as this number decreased. When the number of bolls per plant decreased, however, the number of larvae per form or the intensity of the infestation increased.

The first boll weevil infestation was discovered July 6, when a 1 per cent infestation in squares and a 0.2 per cent infestation in bolls was noted in one field. July 13 may be considered as the first general appearance of the boll weevil infestation, however, as it was noted from three fields on that date. Beginning with the date of its first general appearance, the infestation increased until 51.8 per cent of the squares and 71 per cent of the bolls were infested in one of the fields, September 7. This was the highest point of infestation in bolls noted during the season. The highest point of infestation in squares was reached Sep-

tember 14, when the infestation reached 53.6 per cent in one of the fields. Averaging all four fields together, the peak of the square infestation was reached September 14 at 31.9 per cent, while in bolls the

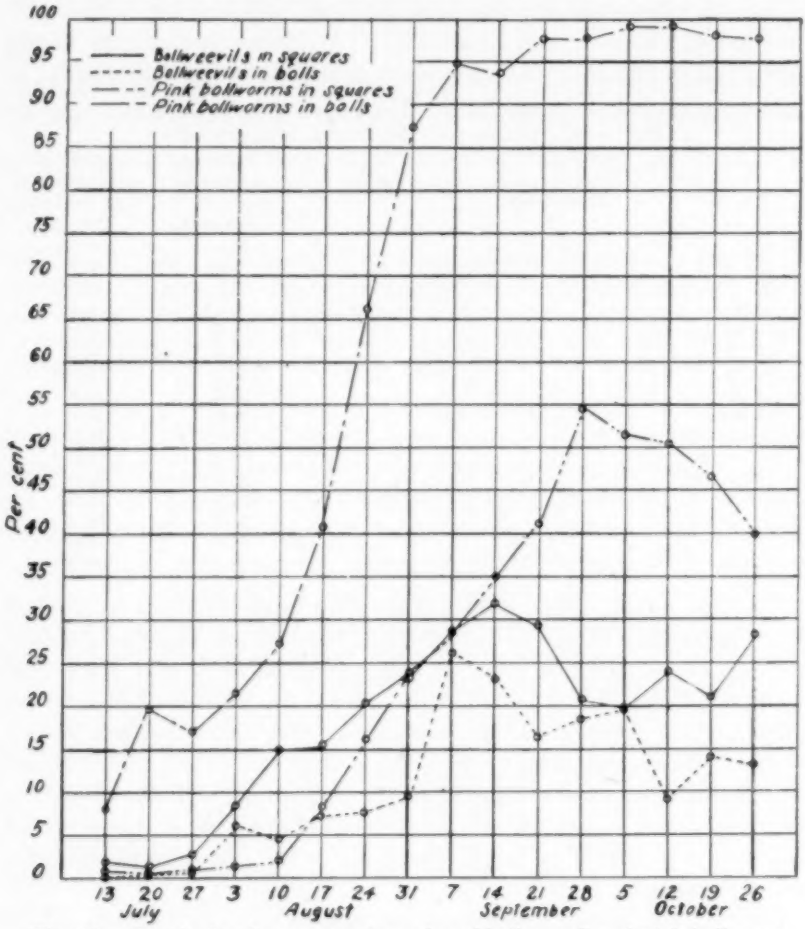


Fig. 41.—Graph showing average intensity of boll weevil and pink bollworm infestation, Tlahualilo, Durango, Mexico, 1931.

highest point of infestation occurred September 7 at 26 per cent. (Tables 1 and 2 and Fig. 41.)

As many as four boll weevil larvae or three pink bollworms were found in a single square. All combinations of the two infestations were observed. All the larvae of both species seemed to be in a healthy condition.

The boll weevil infestation here is peculiar in that it does not run true to form during a dry, hot season. Throughout the cotton belt of the United States, and in the cotton-growing districts generally, a dry, hot season tends to lessen the infestation and damage done by the boll weevil. Such has not been the case during the present season at Tlahualilo. The weather was rather hot and dry, there being only about 4 inches of rainfall during the season.

TABLE 2. AVERAGE INFESTATION IN BOLLS BY THE BOLL WEEVIL AND THE PINK BOLLWORM, TLAHUALILO, DURANGO, MEXICO, 1931

Date 1931	Bolls infested by boll weevil *Per cent*	Bolls infested by pink bollworm *Per cent*
July 13	0	8.0
July 20	.33	19.66
July 27	.5	17.0
August 3	6.0	21.5
August 10	4.5	27.25
August 17	7.0	40.75
August 24	7.5	66.0
August 31	9.25	87.25
September 7	26.0	94.72
September 14	23.0	93.5
September 21	16.25	97.5
September 28	18.33	97.66
October 5	19.66	99.0
October 12	9.0	99.0
October 19	14.0	98.0
October 26	13.0	97.66

Normally the climate at Tlahualilo is hot and dry, there being only from 6 to 8 inches of rainfall annually. This condition necessitates the growing of the cotton by irrigation, the fields being flooded to a depth of from 2 to 3 feet at one flooding during the winter season. The crop is grown from subsoil moisture stored in this manner. Occasionally the fields are irrigated once during the growing season, depending upon the amount of water available and also upon the time at which it becomes available. Under these conditions the boll weevil has only short periods in which the environment is best suited for its growth and development.

PINK BOLLWORM INFESTATION. Pink bollworm infestation was found in squares in all fields examined July 13 but averaged only 0.75 per cent. (Table 1, and Fig. 41.) On the other hand, in bolls, a 2 per cent infestation was found in each of two fields on this same date, and in a third, a 28 per cent infestation was recorded. In the fourth field, a 100-boll sample failed to reveal infestation. The percentage of boll infestation increased with great rapidity from that date, however, and before the season was over 100 per cent of the bolls in each field had

become infested, after which a slight decrease was recorded. Since this complete degree of field infestation was not recorded on the same dates for all fields, the average boll infestation never exceeded 99 per cent. The percentage of square infestation caused by the pink bollworm did not increase nearly so rapidly or reach such a high point. (Tables 1 and 2 and Fig. 41.)

SUMMARY

The boll weevil infestation in cotton at Tlahualilo, Durango, Mexico, in 1931 was considerably heavier than had been recorded since work was resumed with the pink bollworm in 1928. The development of this heavier boll weevil infestation did not retard pink bollworm infestation, which increased in about the same ratio as had been the case in previous years with a slight boll weevil infestation. Neither species appeared to check development and multiplication of the other.

RELATION BETWEEN WIND DISTRIBUTION OF WINGED FORMS AND INFESTATION OF THE TURNIP APHIS, *RHOPALOSIPHUM PSEUDOBRASSICAE* DAVIS

By J. N. RONEY, *Entomologist, Plant Lice Laboratory, Texas Agricultural Experime Station, Dickinson, Texas.*

ABSTRACT

A study of screen collections of the turnip aphis (*Rhopalosiphum pseudobrassicae*) and analyses of the infestations on 30 plantings in several trucking communities show that the infestation of the various plantings has a definite influence on other plantings in the same community. Neglect in controlling an infestation or failure to prevent its spread by plowing the crops under before heavy migration of the aphids begins means the difference between profit and loss to that community.

On the coastal plain of Texas, especially in Galveston and neighboring counties, the truck growers depend mainly on the production of turnips, mustard, and radishes during the winter and spring. In late years the production of these crops has been greatly reduced, largely because of the ravages of the turnip aphis, *Rhopalosiphum pseudobrassicae*. The occurrence of these losses is partially due to the fact that increased prices for greens and other vegetables have caused the risk of late summer plantings to appear more attractive. Such plantings enable the aphids to pass the critical summer period in greater abundance, after which they multiply rapidly and migrate readily to the young fall plantings. The damage caused has been very much in proportion to the number of the late summer plantings, which are usually neglected and

left without being plowed under, in the hope of obtaining a few more bunches of vegetables.

In order to measure the influence of the old, neglected, and infested plantings, investigators at the Plant Lice Laboratory have been obtaining records on the numbers and significance of migratory aphids, their relation to the infestation, and their spread to other plantings.

The Plant Lice Laboratory is located in Galveston County in the middle of an area of about 72 square miles, which contains four trucking communities, Hitchcock, Alta Loma, Dickinson, and League City.

In this area, nine tanglefoot-covered, right-angles screens, size three feet by four feet, were set up with the lower edge two feet above the surface of the ground. These screens were located outside the trucking area of each community, at distances varying from a few feet to one-half mile from truck crops.

The numbers of winged forms of turnip aphids caught daily on the screens were recorded. Also weekly records of infestations were made on 30 plantings of truck in the four communities, during the period October 16 to April 13. Thirteen of these plantings were mustard, 13 were turnip, and 4 were radish. Eight of the 30 plantings were made in October, 8 in December, 9 in January, 3 in February, and 2 in March. It was assumed, therefore, that these plantings would be representative of a typical cross section of the truck crops of the coastal plain and that a study of the migration of aphids from these fall crops would contribute much to the understanding of the importance of the infested and neglected plantings which constitute a menace to the prosperity of the truck growers in that region.

In taking the infestation records of a crop or planting, weekly examinations of 50 leaves were made at each of three points. The percentage of infested leaves was determined, and the number of winged forms that occurred on the leaves was recorded.

Because of the dry summer of 1930, very few plantings were made that season. First counts on the screens were taken September 24, and fall plantings of mustard, turnip, and radish began to come up in abundance by the middle of October. Winged forms were found on half of the plantings by November 1, and by December 1 they had spread to all but one of the plantings. The average number of winged forms per 100 leaves did not exceed eight at any point on any planting during October, November, or December. This shows that the turnip aphis developed very slowly on the fall-planted crops when there were practically no summer plantings from which the aphis could spread. Five of the eight plantings made in December became infested, as soon as they

came up, with winged forms of the turnip aphis, and a similar infestation occurred on seven of the nine plantings made in January. The three exceptions in the December plantings and the two exceptions in the January plantings were approximately all located on the southern edge of the trucking area and next to the open prairie.

With the exception of the March plantings, which became 100 per cent infested as soon as they came up, all plantings of the season became approximately 100 per cent infested between January 22 and February 26, or during a period of 34 days, although the time of planting these crops extended through a period of 119 day days. During February, an average of 210 winged forms per 100 leaves was found at each examination on all plantings. Under such conditions complete destruction takes place as far as commercial value is concerned.

TABLE 1. AVERAGE INITIAL INFESTATION OF THE TURNIP APHIS ON MONTHLY PLANTINGS OF TURNIPS, MUSTARD, AND RADISH; AND THE AVERAGE NUMBER OF WINGED FORMS PER 100 LEAVES EACH MONTH DURING THE GROWING SEASON, 1930–31

Monthly planting	Average infestation first examination		Average number winged forms per 100 leaves						
	Leaves per cent	No. winged forms per 100 plants	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Oct. 16....	22.2	1.4	1	2	3	41	288	160	126
Dec. 11–19.	28.3	3.4	—	—	3	35	247	468	—
Jan. 8–22..	24.9	6.4	—	—	—	10	89	263	—
Feb. 5–12..	62.6	48.6	—	—	—	—	74	—	—
Mar. 5–19.	98.0	96.0	—	—	—	—	—	106	—
Average of 30 plantings.....			1.2	2.1	3.2	30.1	210.3	248	126

Table 1 shows the average initial infestation on the various monthly plantings, and the average number of winged forms per 100 leaves during each month of the growing season. The percentage of leaves infested and the number of winged forms found on the first examinations of the monthly plantings showed very little increase during the period from October to January, inclusive. But the average number of winged forms on each examination of all plantings was 10 times greater in January than in December and increased in February almost in geometrical proportion again, being seven times greater than that in January.

On February 1, the October plantings were 107 days old. With the exception of two of these plantings, all plantings of the season were neglected and not destroyed until the plants were practically all dead.

None of the January plantings produced good marketable vegetables, although the fall of 1930 was about as favorable as could be expected, since the aphis infestation developed very slowly because of the absence of summer truck crops.

Three of the nine screens, 1, 3, and 7 (Fig. 42), were located close to truck patches, but at the margin of the prairie, from which the prevailing winds blow. Screens 5, 8, and 9 were also close to truck but on the lee side. The numbers of winged forms of plant lice caught each

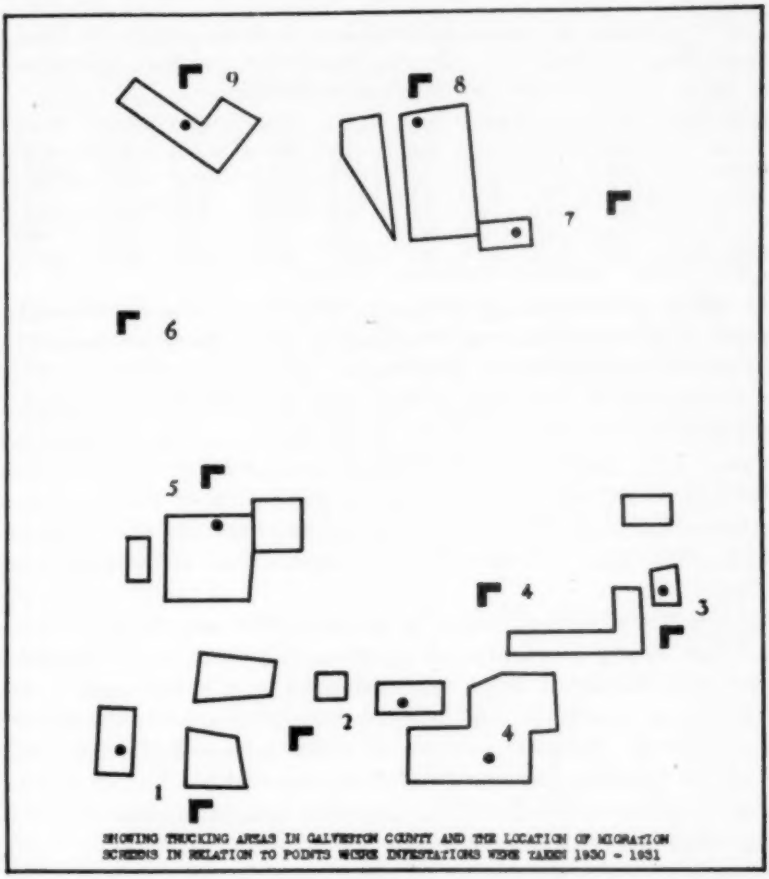


FIG. 42

month on these two groups of screens are shown in Table 2, in comparison with the average number caught on all screens.

The difference in the catch of the two groups of screens is due to their locations and shows the importance of the wind as a factor in the distribution of the winged aphids. Some are also carried in a direction opposite to that of the prevailing winds, this movement being recorded on Screens 1, 3, and 7. Such distribution and movement show the

danger in the infested plantings that are neglected. The large increase in the screen catch of February was preceded in the latter half of January by an infestation which occurred on 56 per cent of all leaves on all plantings.

TABLE 2. COMPARISON OF THE AVERAGE NUMBER OF WINGED FORMS OF TURNIP APHIDS CAUGHT ON TANGLEFOOT-COVERED SCREENS DURING EACH MONTH OF THE GROWING SEASON, 1930–31

Screens No.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
1, 3, 7	0.3	19.3	16.0	0.6	2.3	286	112.6	2.6	439.7
5, 8, 9	0.0	14.3	12.6	1.6	60.6	1711.6	604.0	56.6	2461.3
2	1.0	60.0	50.0	6.0	11.0	231.0	66.0	14.0	439.0
4	0.0	12.0	19.0	3.0	9.0	387.0	154.0	20.0	604.0
6	0.0	6.0	3.0	0.0	1.0	27.0	16.0	1.0	54.0
All except No. 6	0.2	21.6	19.4	2.1	26.1	826.3	296.3	26.5	1218.5

The effect of some plantings upon others in the same community, especially when in line with the prevailing winds, is illustrated in the duration of the plantings before they became 100 per cent infested. They averaged 70 days at point number 4, as compared with 51 days duration for the plantings at point number 2, which was about one-fourth to one mile away from plantings of which point number 4 was representative. A duration of 126 days for plantings at point number 7 as compared with a duration of 65 days for the plantings at point number 8 is another example of the effect of some plantings upon others in the same community.

The number of winged forms of turnip aphids caught on screen 4 shows that nearly one-fourth as many aphids were being carried a quarter of a mile away from truck crops as were being caught close to the crops, as exemplified by the catch on an area equal to the size of a screen, Table 2. Screen 6 was located three and one-half miles northwest of the trucking community of Alta Loma with a barrier of trees between. A few of the turnip aphids were caught on this screen although the numbers were negligible.

A study of the screen catch of turnip aphids and analyses of the infestation records show that an infestation on crops in one part of a community has a definite influence on other plantings in the same community, especially when in line with the prevailing winds. When the crops are grown intensively for commercial purposes, neglect in controlling an infestation, or failure to prevent its spread by plowing the crops under before heavy migration of the aphids begins, means the difference between profit and loss to that community.

OBSERVATIONS ON THE BIOLOGY OF THE PEACH BORER IN ROANE COUNTY, TENNESSEE, HARRIMAN, TENN., 1931

By H. G. BUTLER, *U. S. Bureau of Entomology*[1]

ABSTRACT

This paper reports observations on the biology of the peach borer (*Synanthedon exitiosa* Say) and the results of control experiments in eastern Tennessee during the fall of 1930 and the summer of 1931. In this area October 1 is considered to be near the optimum date for control treatments. The peak period of emergence of adults of the peach borer occurred between September 4 and September 7. The average potential oviposition of 25 moths was 767.2 eggs each during the season of 1931.

The study of the peach borer (*Synanthedon exitiosa* Say) herein presented was designed to determine the approximate limits within which successful treatments for borer control could be made. The work was carried out in an orchard about 7 miles south of Harriman, Tenn.

There is an exceptionally heavy borer infestation in this orchard. No treatment for borer control was made in 1929 but this is said to have been the first year treatment was omitted.

EXPERIMENTAL TREATMENTS. A standard application of 1 ounce of paradichlorobenzene was applied in a circle about the base of the experimental trees. Applications were made September 15, October 1, October 15, and November 1, 1930.

As some information was desired in regard to the period of exposure, the paradichlorobenzene was removed from some of the trees after four weeks' exposure, from others after six weeks' exposure, and a third group was exposed to treatment until January 25.

In order to secure a more uniform distribution in the experimental area the trees treated on the various dates were distributed in blocks of five each, thus giving duplicate blocks for each of the combinations under test. Subsequent to treatment the blocks were so divided that those having the same period of exposure to the toxic material were grouped together. This provided 40 trees each for the four weeks' and six weeks' exposure blocks and 75 trees for the block exposed until January 25. The 45 untreated check trees were placed at regular intervals throughout the entire experimental area.

Part of the trees were used to determine the effects of treatment by fall examination. This was carried out by removing the earth from the

[1]Mr. R. G. Adkisson, Temporary Field Assistant, was employed between June 3 and September 11, 1931. During this time he made most of the field-emergence observations.

immediate vicinity of the base of the trees and cutting away such bark as was necessary to expose the larvae.

The larvae found which showed no readily observed effects of treatment were scored as normal; those showing discoloration, a flaccid condition, or failing to respond to the stimulus of touch, as dead; and those which were quite sluggish but still gave unmistakable signs of life, as stupefied.

Examinations were made of trees treated on each of the four dates after an exposure of four and six weeks to the toxic action of paradichlorobenzene. In Table 1 are given the results obtained from the examination of trees exposed to this treatment for a period of four weeks and in Table 2 the results obtained from trees exposed to treatment for six weeks.

TABLE 1. RESULTS OF EXAMINATION OF TREES EXPOSED TO THE TOXIC ACTION OF PARADICHLOROBENZENE FOR A PERIOD OF FOUR WEEKS, HARRIMAN, TENN. 1931

Date of treatment	Treated trees				Untreated trees			
	Number of trees	Number of larvae			Number of trees	Number of larvae		
		Normal	Stupified	Dead		Normal	Stupified	Dead
Sept. 15..	10	0	15	101	5	23	0	1
Per cent..			13	87		96		4
Oct. 1....	10	1	74	95	5	101	0	0
Per cent..			43	56		100		
Oct. 15...	10	21	85	137	5	126	0	3
Per cent..		9	35	56		98		2
Nov. 1....	10	117	72	111	5	71	0	2
Per cent..		39	24	37		97		3

TABLE 2. RESULTS OF THE EXAMINATION OF TREES EXPOSED TO THE TOXIC ACTION OF PARADICHLOROBENZENE FOR A PERIOD OF SIX WEEKS, HARRIMAN, TENN., 1930

Date of treatment	Treated trees				Untreated trees			
	Number of trees	Number of larvae			Number of trees	Number of larvae		
		Normal	Stupified	Dead		Normal	Stupified	Dead
Sept. 15..	10	0	1	50	5	115	0	0
Per cent..			2	98		100		
Oct. 1....	10	0	18	132	5	126	0	3
Per cent..			12	88		98		2
Oct. 15...	10	22	62	155	5	164	0	2
Per cent..		9	26	65		99		1
Nov. 1....	15	158	92	230	5	187	0	5
Per cent..		33	19	48		97		3

The results of the various treatments were also determined by the emergence of moths (as indicated by the presence of cast pupal skins) in the various plats during the summer following the treatment. The figure used for the infestation of the check tree is the average of those obtained from the 45 trees used for this purpose. These emergence records are shown in Table 3.

TABLE 3. SUMMARY OF THE EMERGENCE OF ADULTS OF THE PEACH BORER FROM EXPERIMENTAL TREES, HARRIMAN, TENN., 1931

Date of treatment	Period of exposure in weeks	Number of trees	Average number of moths per tree	Per cent of check emergence	Per cent reduction obtained
Sept. 15.....	4	10	3.8	15.4	84.6
Oct. 1.....	4	10	12.2	49.3	50.7
Oct. 15.....	4	10	11.1	44.8	55.2
Nov. 1.....	4	10	15.7	63.4	36.6
Sept. 15.....	6	10	11.0	44.4	55.6
Oct. 1.....	6	10	6.5	26.3	73.7
Oct. 15.....	6	10	8.0	32.3	67.7
Nov. 1.....	6	10	13.0	52.5	47.5
Sept. 15.....	19	20	5.2	21.0	79.0
Oct. 1.....	17	20	3.2	12.9	87.1
Oct. 15.....	15	20	3.7	14.9	85.1
Nov. 1.....	12	15	10.2	41.2	58.8
Untreated check trees.....		45	24.75	100.0	0.0

The high degree of control obtained in the block treated September 15 and subjected to four weeks' exposure is partly explained by the fact that no moths emerged from 4 of the 10 trees in the block. Whether this was due to an actual 100 per cent control of the borers in these 4 trees or to the absence of an initial infestation is unknown. Blocks treated September 15 and exposed to six weeks' and nineteen weeks' treatment do not offer supporting evidence that this is the optimum date for treatment. If the optimum date for treatment is selected from those blocks having a longer period of exposure, the October 1 treatment is clearly superior to the others.

In comparing the results secured from trees exposed to treatment for six weeks with those treated on the same dates and exposed for a longer period, it is noted that in each case the longer period of exposure gave a higher degree of control.

RATE OF MOTH EMERGENCE. Daily observations for the emergence of moths from the soil were started June 11 and continued until September 21. The emergence of moths was determined by the presence of the cast pupal skins. The first emergence was noted on June 11. In Table 4 is given a weekly summary of the adults of the peach borer recorded as emerging from the trees under observation.

The rate of emergence remained at a relatively low level until August 28. Between August 27 and September 16 a total of 1,569 moths were recorded as emerging from the treated and check trees under observation. This rather brief period furnished 67.5 per cent of the emergence for the season. The actual peak of emergence occurred from September 4 to September 7.

TABLE 4. SUMMARY OF THE EMERGENCE OF ADULTS OF THE PEACH BORER FROM EXPERIMENTAL TREES AT HARRIMAN, TENN., 1931

Period From	To	Number of moths emerged	Per cent of total emergence	Period From	To	Number of moths emerged	Per cent of total emergence
June 11	June 17	23	1.0	Aug. 6	Aug. 12	37	1.6
18	24	57	2.5	13	19	105	4.5
25	July 1	73	3.1	20	26	103	4.4
July 2	8	83	3.6	27	Sept. 2	490	21.1
9	15	43	1.9	Sept. 3	9	827	35.6
16	22	50	2.2	10	16	252	10.9
23	29	66	2.8	17	21	71	3.0
30	Aug. 5	42	1.8	Total.....		2,322	100.0

DISTRIBUTION OF EMERGENCE. To protect the pupating forms against predators, a screen-wire barrier (Fig. 43) was installed about the base of each of the experimental trees. This barrier was made of a strip of

Fig. 43.—Peach tree with screen-wire barrier.

galvanized screening, 6 inches wide and 48 inches long, forming, when in place, a circular enclosure about 15 inches in diameter. In the course of making the daily observations it was noted that while most of the moths were emerging inside the wire barriers a considerable number were emerging outside of this area. This field of emergence apparently extended for a distance of 30 inches from the trunk of the tree. In order to obtain specific information on this point the daily emergence record was so taken as to give the number of moths emerging inside the barrier, those emerging outside and within a foot of the barrier, and those emerging at a greater distance from the tree.

Between September 5 and September 21 the records of the emergence of moths were taken in this way. During this time a total of 933 moths

emerged. These emerged as follows: 529 moths, or 56.7 per cent, emerged within the barrier; 342 moths, or 36.7 per cent, emerged within 1 foot of the barrier; and 62 moths, or 6.6 per cent, emerged at a greater distance from the tree.

TABLE 5. INDIVIDUAL OVIPOSITION RECORD OF 25 ADULTS OF THE PEACH BORER, HARRIMAN, TENN., 1931

Moth number	Date of emergence	Longevity in days	Number of eggs laid	Dissection count	Potential oviposition
1	June 21	*	714	395	1,109
2	22	9	374	405	779
3	22	*	365	349	714
4	23	12	463	379	842
5	23	*	207	310	517
6	25	9	367	302	669
7	25	9	490	313	803
8	26	*	493	410	903
9	28	9	538	697	1,235
10	29	*	163	244	407
11	July 2	10	300	433	733
12	4	13	475	23	498
13	5	6	49	646	695
14	10	9	635	76	711
15	24	10	255	676	931
16	26	9	647	257	904
17	27	5	470	73	543
18	28	7	259	430	689
19	28	9	360	334	694
20	28	7	257	362	619
21	28	6	212	399	611
22	30	12	785	11	796
23	Aug. 1	7	630	38	668
24	18	12	308	462	770
25	25	6	13	1,328	1,341
Maximum		13	785	1,328	1,341
Minimum		5	13	11	407
Average		8.8	393.2	374.1	767.2

*Date of death not recorded.

PREDATORS. About June 15 the first work of predators removing the pupating forms from the base of the trees was noted. This depredation continued for the rest of the season, being especially noticeable the first few days following a rain. The identity of this predator is not known.

With few exceptions this attack on the pupating borers was successfully repelled by the screen-wire barriers. On the outside of the barriers, however, a large proportion of the pupating forms were destroyed by the predators.

INSECTARY STUDIES. Studies of the potential oviposition capacity of the peach borer were carried out at the insectary. The moths used for this purpose were reared from field-collected pupae and emerged at the insectary. They are regarded as unfertilized females. In several cases it was noticed that oviposition began on the day of emergence from the soil.

Newly emerged adults were allowed a period for their wings to harden and then confined in petri dishes for oviposition records. These dishes were changed daily and a record taken of the number of eggs deposited. A moistened sponge in the petri dish provided water for the moths. At the death of a moth a dissection was made and the number of eggs found added to the number deposited to give the potential oviposition. The individual oviposition record of 25 moths is given in Table 5.

INCUBATION. Moths taken in the orchard were confined in petri dishes and the eggs so obtained used for incubation records. It was found that if moisture was supplied these eggs would hatch. The average incubation period of 421 eggs was 9.2 days, the minimum 7 days, and the maximum 12 days.

A NEW METHOD OF CONTROLLING THE PEACH BORER, *SYNANTHEDON EXITIOSA* SAY, WITH SPECIAL APPLICATION TO YOUNG TREES

By OLIVER I. SNAPP, *Entomologist, Peach Insect Laboratory, U. S. Bureau of Entomology, Fort Valley, Ga.*

ABSTRACT

Experiments with paradichlorobenzene-crude cottonseed oil emulsion applied as a spray at various strengths on peach trees one, two, three, six, and seven years old were conducted during the seasons of 1930 and 1931. The experiments of 1931 included also paradichlorobenzene-mineral oil emulsion and naphthalene-crude cottonseed oil emulsion applied as sprays at various strengths and paradichlorobenzene crystals and naphthalene crystals applied in a continuous band on the ground about 1½ inches from the tree trunk. Paradichlorobenzene-oil emulsions carrying one-fourth ounce of the chemical to each one- or two-year-old tree, one-half ounce to each three-year-old tree, and 1 ounce to each six or seven-year-old tree, with several shovelfuls of soil placed around the tree after spraying, proved to be safe and very effective against the peach borer. Those emulsions applied as sprays are apparently the only safe means of controlling the peach borer in one, two, and three-year-old peach trees under conditions in the South. This method of peach-borer control for older trees is an improvement over the paradichlorobenzene-crystal treatment, as it is easier to use and takes less time for the application. Naphthalene-crude cottonseed oil emulsion and naphthalene crystals were injurious to peach trees and not effective against the peach borer.

Field experiments and laboratory investigations with paradichlorobenzene for the control of the peach borer (*Synanthedon exitiosa* Say) have been a major project at the Fort Valley, Ga., laboratory during the last eleven years. Special attention has been given to the possibility of extending the use of this chemical to young trees, and to a study of tree

injury from its use under different weather conditions. The severe injury to young peach trees from the use of paradichlorobenzene crystals under the weather conditions that prevailed at Fort Valley, Ga., during October, 1923, has been reported.[1] Again in October, 1928, severe injury to young peach trees occurred as a result of high temperatures causing a rapid generation of gas from the paradichlorobenzene crystals.[2] Work on the project during the last three years has been confined almost entirely to investigations dealing with the control of the insect in one, two, and three-year-old peach trees, since the paradichlorobenzene crystal treatment is considered safe for trees four years of age and older. The results of these investigations are given now as a report of progress, since they seem to offer a solution to the problem of peach-borer control in young peach trees. Furthermore, an apparent improvement over the paradichlorobenzene crystal treatment for peach-borer control in the older trees is presented.

The experiments of 1929 consisted chiefly of investigations dealing with paradichlorobenzene dissolved in vegetable oil applied to the trunks of the trees with a paint brush. All sides of the trunk above and below the soil were treated. While this treatment gave excellent borer control, more or less injury to the tree resulted. An emulsion of paradichlorobenzene in vegetable oil was also used in 1929, the material being poured around the trees. While variable results were obtained, they prompted extensive experimentation the following year with paradichlorobenzene-crude cottonseed oil emulsion applied as a spray. This spray gave excellent borer control with no tree injury, even on the youngest trees. Further experimentation with the emulsion during the fall of 1931 added results on the value of this spray for peach-borer control.

Experiments of 1930

Paradichlorobenzene-crude cottonseed oil emulsion at various strengths was used on one, two, three, and seven-year-old trees during the fall of 1930. The emulsion was made by dissolving paradichlorobenzene in crude cottonseed oil in the proportion of 2 pounds of the chemical to each gallon of oil and then emulsifying the mixture with a good grade of potash fish-oil soap. The stock emulsion was then diluted with water so that ½ or 1 pint contained the desired dosage of paradichlorobenzene for each

[1]Snapp, O. I. Paradichlorobenzene experiments in the south for peach-borer control. U. S. Dept. Agr., Bul. 58, 39 p., illus.

[2]Snapp, O. I., and Swingle, H. S. Results of further investigations with paradichlorobenzene around peach trees with special reference to injury. J. Econ. Entom. 22:782–785. 1929.

TABLE 1. RESULTS OBTAINED FROM SPRAYING THE BASE OF PEACH TREES WITH PARADICHLOROBENZENE-CRUDE COTTONSEED OIL EMULSION[1] FOR THE CONTROL OF THE PEACH BORER. FORT VALLEY, GA., 1930

Plat No.	Number trees	Paradichloro-benzene received by each tree	Dates sprayed	Mounded after application	Date examined for borers	Mortality of borers	Injury to trees
			One-year-old trees				
		Ounce				*Per cent*	
1	5	⅛	Sept. 22 and Oct. 2	No	Oct. 16	No borers in trees	None
2	5	⅛	Oct. 2 and 13	No	Oct. 27	Do.	Do.
3	5	¼	Sept. 22 and Oct. 2	No	Oct. 16	Do.	Do.
4	5	¼	Oct. 2 and 13	No	Oct. 27	Do.	Do.
5	5	¼	Oct. 13	Yes	Oct. 27	100.0	Do.
6	5	½	Oct. 13	Yes	Oct. 27	No borers in trees	Do.
7	8	Check	Untreated		Oct. 27	Do.	Do.
			Two-year-old trees				
1	5	⅛	Sept. 22 and Oct. 2	No	Oct. 16	No borers in trees	None
2	5	⅛	Oct. 2 and 13	No	Oct. 27	0.0	Do.
3	5	¼	Sept. 22 and Oct. 2	No	Oct. 16	No borers in trees	Do.
4	5	¼	Oct. 2 and 13	No	Oct. 27	0.0	Do.
5	5	¼	Oct. 13	Yes	Oct. 27	No borers in trees	Do.
6	5	½	Oct. 13	Yes	Oct. 27	Do.	Do.
7	5	¾	Oct. 13	Yes	Oct. 27	100.0	4 trees showed injury in the fall; there were flecks into the cambium of 3 trees, and in the 4th the flecks had converged into sour areas which went through bark layers but not into cambium. On April 24 the injury was about the same, but by August 11 one injured tree had recovered and the injury was less on 2 others
8	10	Check	Untreated		Oct. 27	0.0	None

				Three-year-old trees			
1	4	¼	Sept. 22 and Oct. 2	No	Oct. 16	1 live borer deep in gallery of a crown gall	None
2	4	¼	Oct. 2 and 13	No	Oct. 27	No borers in trees	Do.
3	4	⅜	Sept. 22 and Oct. 2	No	Oct. 16	100.0	Do.
4	4	⅜	Oct. 2 and 13	No	Oct. 27	No borers in trees	Do.
5	3	¼	Oct. 13	Yes	Oct. 27	100.0	Do.
6	3	¼	Oct. 13	No	Oct. 27	50.0	Do.
7	3	½	Oct. 13	Yes	Oct. 27	100.0 (some deep in galleries)	Do.
8	3	½	Oct. 13	No	Oct. 27	No borers in trees	Do.
9	3	¾	Oct. 13	Yes	Oct. 27	100.0 (1 deep in gallery)	Do.
10	3	¾	Oct. 13	No	Oct. 27	100.0 (1 deep in gallery)	Do.
11	5	Check	Untreated		Oct. 27	0.0	Do.
				Seven-year-old trees			
1	5	1	Oct. 14	Yes	Nov. 18	100.0	None
2	5	1	Oct. 14	No	Nov. 18	60.0	Do.
3	5	Check	Untreated		Nov. 18	3.7	Do.

[1]One, two, and three-year-old trees received the paradichlorobenzene in ½ pint of emulsion at each application, the seven-year-old trees in 1 pint of emulsion at each application.

tree. All applications were made with a sprayer at a pressure of from 25 to 50 pounds, and the emulsion was sprayed on the ground around the tree and on the lower part of the trunk. In some cases the trees were mounded after treatment by placing several shovelfuls of soil around each tree. Three examinations for tree injury were made, in the fall of 1930 and in the spring and summer of 1931. Table 1 gives the results of these experiments.

DISCUSSION OF RESULTS. *One-year-old trees* were in no way injured from one application of a spray of paradichlorobenzene-crude cottonseed oil emulsion carrying one-fourth or one-half ounce of the chemical to each tree and mounded or from two applications of the spray carrying one-eighth or one-fourth ounce of the chemical to each tree at each application but not mounded. One application of the spray carrying one-fourth ounce of the chemical to each tree and mounded gave a 100 per cent control of the peach borer.

Two-year-old trees were in no way injured from one application of a spray of paradichlorobenzene-crude cottonseed oil emulsion carrying one-fourth or one-half ounce of the chemical to each tree and mounded, or from two applications of the spray carrying one-eighth or one-fourth ounce of the chemical to each tree at each application but not mounded. One application of the spray carrying three-fourths ounce of the chemical to each tree and mounded resulted in some injury. Evidently it is not safe to use more than one-half ounce of the chemical per tree when spraying two-year-old trees. Two applications of the spray carrying one-eighth or one-fourth ounce of the chemical to each tree at each application but not mounded were not effective against the peach borer. There were no borers in trees sprayed once with the emulsion carrying one-fourth or one-half ounce of the chemical to each tree and mounded. All borers were dead in the trees sprayed once with the emulsion carrying three-fourths ounce of the chemical to each tree and mounded.

Three-year-old trees were in no way injured from one application of a spray of paradichlorobenzene-crude cottonseed oil emulsion carrying one-fourth, one-half, or three-fourths ounce of the chemical to each tree whether mounded or not, or from two applications of the spray carrying one-fourth or three-eighths ounce of the chemical to each tree at each application but not mounded. One application of the spray carrying one-fourth ounce of the chemical to each tree and mounded gave a 100 per cent control of the peach borer, but the same treatment gave only a 50 per cent control when the trees were not mounded after spraying. Evidently better control can be obtained by placing several shovelfuls of soil around the tree after it is sprayed. One application of the spray

carrying one-half or three-fourths ounce of the chemical to each tree and mounded gave a 100 per cent control of the borers, even though some of them were very deep in their galleries. One application of spray carrying three-fourths ounce of the chemical to each tree but not mounded gave a 100 per cent control. There were no borers in trees sprayed once with the emulsion carrying one-half ounce of paradichlorobenzene to each tree but not mounded. One hundred per cent control of the borers was obtained by spraying the trees twice with the emulsion carrying three-eighths ounce of the chemical to each tree at each application and not mounded.

Seven-year-old trees were in no way injured from one application of a spray of paradichlorobenzene-crude cottonseed oil emulsion carrying 1 ounce of the chemical to each tree, whether mounded or not. When the trees were mounded the spray gave a 100 per cent control of the peach borer, but when not mounded only a 60 per cent control was obtained. So here again mounding the trees after spraying increased the effectiveness of the spray. This method of peach-borer control for old trees is an apparent improvement over the paradichlorobenzene-crystal treatment, as less time is required for the application and it is easier to use. Furthermore, it would be more effective than crystals in those districts where borers infest the peach-tree roots that are more or less exposed as a result of hillside washing of the soil.

Aside from the high rate of mortality of the borers from the emulsion, the most interesting observation was the rapidity of action from the spray. In many cases only the heads of borers could be found five weeks after treatment, the bodies having completely decomposed during that period. On that account many borers were missed in the treated trees when examinations were made for borer mortality. An average of 5.4 borers per tree were found in the check trees, whereas only 2.2 borers per tree were found in the treated trees. Apparently paradichlorobenzene gas from paradichlorobenezene-crude cottonseed oil emulsion is given off rapidly, and the entire dosage is soon spent. For that reason, in addition to its being as toxic, if not more so, to insects, the emulsion is perhaps safer for trees than paradichlorobenzene crystals.

Experiments of 1931

Experiments with paradichlorobenzene-crude cottonseed oil emulsion at various strengths were continued during the fall of 1931, and in addition experiments were conducted at that time with paradichlorobenzene-mineral oil emulsion and naphthalene-crude cottonseed oil emulsion at various strengths. Paradichlorobenzene crystals and naphthalene

TABLE 2. RESULTS OBTAINED FROM SPRAYING THE BASE OF PEACH TREES WITH VARIOUS EMULSIONS AND FROM CHEMICALS IN CRYSTAL FORM FOR THE CONTROL OF THE PEACH BORER. FORT VALLEY, GA., 1931

One-year-old trees

Plat No.	Number of trees	Treatment	Chemical per tree *Ounce*	Date of application	Mounded after application	Date examined for borers	Mortality of borers *Per cent*	Injury to trees on date examined for borers
1	5	Paradichlorobenzene-crude cottonseed oil emulsion	⅛	Oct. 12	No	Oct. 26	No borers in trees	None
2	5	Do.	¼	Do.	No	Do.	Do.	Do.
3	5	Do.	¼	Do.	Yes	Do.	Do.	Do.
4	5	Do.	½	Do.	No	Do.	Do.	Do.
5	5	Paradichlorobenzene-mineral-oil emulsion	⅛	Do.	No	Do.	Do.	Do.
6	5	Do.	¼	Do.	No	Do.	Do.	Do.
7	5	Do.	½	Do.	No	Do.	Do.	Do.
8	5	Naphthalene-crude cottonseed oil emulsion	¼	Oct. 15	No	Nov. 13	Do.	Cambium severely injured half way around one tree
9	5	Check		Untreated		Oct. 26	Do.	None
10	5	Paradichlorobenzene crystals	½	Oct. 12	Yes	3 trees on Oct. 29	Do.	Do.
						2 trees on Nov. 13	Do.	1 tree severely injured into cambium, may die
11	5	Naphthalene crystals	½	Oct. 12	Yes	2 trees on Oct. 29	No borers in trees	None
						3 trees on Nov. 13	Do.	Cambium discolored half way around tree, no bark injury

					Two-year-old trees			
1	5	Paradichlorobenzene-crude cottonseed oil emulsion	¼	Oct. 12	No	Oct. 26	33.3 (also live dipterous larvae)	None
2	5	Do.	¼	Do.	Yes	Do.	100.0	Do.
3	5	Do.	½	Oct. 13	No	Do.	80.0	Do.
4	5	Paradichlorobenzene-mineral oil emulsion	¼	Do.	No	Do.	50.0	Do.
5	5	Do.	¼	Do.	Yes	Do.	100.0	Do.
6	5	Do.	½	Do.	No	Do.	33.3	Do.
7	5	Naphthalene-crude cottonseed oil emulsion	¼	Do.	No	Oct. 29	No borers in trees	Do.
8	5	Do.	½	Do.	No	1 tree on Oct. 29	Do.	Do.
						4 trees on Nov. 12	Do.	Cambium of 2 trees severely injured
9	5	Check		Untreated		Oct. 29	Do.	None
10	5	Paradichlorobenzene crystals	½	Oct. 15	Yes	Do.	100.0	2 trees severely flecked into cambium, 1 tree moderately flecked into cambium, and flecks just starting in bark layers of another
11	5	Naphthalene crystals	½	Do.	Yes	2 trees on Oct. 29	No borers in trees	None
						3 trees on Nov. 12	Do.	1 tree severely injured into cambium, and cambium of another discolored.

Three-year-old trees

1	5	Paradichlorobenzene-crude cottonseed oil emulsion	¼	Oct. 12	Yes	Oct. 26	100.0	None
2	5	Do.	½	Do.	No	Do.	58.3	Do.
3	5	Do.	½	Oct. 13	Yes	Do.	66.7	Do.
4	4	Do.	¾	Do.	Yes	Do.	100.0	Do.
5	5	Paradichlorobenzene-mineral oil emulsion	¼	Do.	Yes	Do.	85.7	Do.
6	5	Do.	½	Do.	No	Do.	50.0	Do.
7	5	Do.	½	Do.	Yes	Do.	100.0	Do.
8	5	Do.	¾	Do.	Yes	Do.	100.0	2 trees severely flecked into cambium with sour spots, 1 tree lightly flecked in bark layers
9	5	Naphthalene-crude cottonseed oil emulsion	¼	Oct. 15	No	1 tree on Oct. 29 4 trees on Nov. 12	0.0 0.0	None Cambium discolored around 1 tree
10	5	Do.	½	Do.	No	Nov. 12	No borers in trees	Cambium of 3 trees severely injured
11	5	Do.	¾	Do.	No	Do.	0.0	All trees severely injured into cambium from one-third to all way around tree
12	5	Paradichlorobenzene crystals	¾	Do.	Yes	Oct. 29	100.0	3 trees moderately to severely flecked into cambium, some sour spots in bark layers
13	5	Check		Untreated		Do.	0.0	None
14	5	Naphthalene crystals	¾	Oct. 15	Yes	2 trees on Oct. 29 3 trees on Nov. 12	0.0 0.0	Do. Cambium of 2 trees severely injured

					Six-year-old trees			
1	10	Paradichlorobenzene-crude cottonseed oil emulsion	1	Oct. 14	Yes	Oct. 28	100.0	1 or 2 sour spots about 1 sq. in. on 2 trees where spray puddled, some of these spots into cambium
2	10	Do.	1	Do.	No	Do.	75.0	1 or 2 sour spots about 1 sq. in on 1 tree where spray puddled, some of these spots into cambium
3	10	Paradichlorobenzene-mineral oil emulsion	1	Do.	Yes	Oct. 29	95.7	1 or 2 sour spots about 1 sq. in. on 1 tree where spray puddled, some of these spots into cambium
4	10	Do.	1	Do.	No	Do.	94.7	None
5	10	Naphthalene-crude cottonseed oil emulsion	1	Do.	Yes	5 trees on Oct. 29	57.1	Do.
						5 trees on Nov. 13	0.0	Cambium of 3 trees severely injured
6	10	Do.	1	Do.	No	5 trees on Oct. 29	20.0	None
						5 trees on Nov. 13	0.0	Cambium of 2 trees moderately injured
7	10	Paradichlorobenzene crystals	1	Do.	Yes	Oct. 29	100.0	None
8	10	Naphthalene-crystals	1	Do.	Yes	1 tree on Oct. 29	0.0	Do.
						9 trees on Nov. 13	0.0	Cambium of 3 trees severely injured
9	10	Check		Untreated		Oct. 29	2.4	None

crystals were also used for comparative results on borer mortality and tree injury. The emulsions were made by dissolving 2 pounds of the chemical in each gallon of oil, and then emulsifying the mixture with a good grade of potash fish-oil soap. An asphaltic-base mineral oil having a viscosity of about 235 seconds Saybolt at 100° F. and a volatility (loss during four hours at 105° C.) of 0.09 per cent was used for the paradichlorobenzene-mineral oil emulsion. The stock emulsions were diluted with water so that 1 pint contained the desired dosage of the chemical for each tree. The emulsions were applied with a sprayer at a pressure of about 50 pounds, and they were sprayed on the ground around the tree and on the lower part of the trunk. The crystals were applied on the ground in a continuous band about 1½ inches wide and 1½ inches from the tree trunk, as recommended. Table 2 gives the results of the experiments of 1931.

Discussion of Results. *One-year-old trees* were in no way injured from an application of a spray of paradichlorobenzene-crude cottonseed oil emulsion carrying one-eighth, one-fourth, or one-half ounce of the chemical to each tree but not mounded or from the same spray carrying one-fourth ounce of the chemical and mounded. Likewise, no injury resulted from an application of paradichlorobenzene-mineral oil emulsion spray carrying one-eighth, one-fourth, or one-half ounce of the chemical to each tree but not mounded. After four weeks' exposure naphthalene-crude cottonseed oil emulsion carrying one-fourth ounce of the chemical to each tree but not mounded severely injured the cambium of one of the five trees sprayed with that material. Paradichlorobenzene crystals and naphthalene crystals at the rate of one-half ounce per tree produced no injury at the end of two weeks, but caused severe injury at the end of four weeks. One-year-old peach trees are seldom infested with the peach borer. Not a borer was found in the trees used for these experiments. Therefore, no data are available on the mortality of borers from the treatments used on the one-year-old trees in 1931.

Two-year-old trees. There was no injury whatever to two-year old trees sprayed with paradichlorobenzene-crude cottonseed oil emulsion or paradichlorobenzene-mineral oil emulsion carrying one-fourth ounce of the chemical to each tree whether mounded or not, or from the emulsions carrying one-half ounce of the chemical but not mounded. Napthalene-crude cottonseed oil emulsion carrying one-fourth or one-half ounce of the chemical to each tree did not injure the trees after an exposure of two weeks but at the end of four weeks that spray carrying one-half ounce of the chemical caused severe cambium injury. The one-half ounce dose of paradichlorobenzene crystals caused

severe injury to trees from just a two weeks' exposure under weather conditions that prevailed during the fall of 1931. The one-half ounce dose of naphthalene crystals caused no injury to the trees at the end of two weeks but produced severe injury at the end of four weeks.

Paradichlorobenzene-crude cottonseed oil emulsion and paradichlorobenzene-mineral oil emulsion carrying one-fourth ounce of the chemical to each tree and covered with soil gave a 100 per cent mortality of the borers. When not mounded, the same dosage of paradichlorobenzene-crude cottonseed oil emulsion gave only 33.3 per cent control and the same dosage of paradichlorobenzene-mineral oil emulsion gave only 50 per cent control. The paradichlorobenzene emulsions carrying one-half ounce to each tree and not mounded gave an 80 per cent control for the spray made with crude cottonseed oil and 33.3 per cent control for the spray made with mineral oil. The one-half ounce dose of paradichlorobenzene crystals around two-year-old trees gave a 100 per cent borer mortality.

Three-year-old trees. No injury resulted from the use of paradichlorobenzene-crude cottonseed oil emulsion or paradichlorobenzene-mineral oil emulsion around three-year-old peach trees at the rate of one-half ounce of the chemical per tree whether mounded or not or one-fourth ounce of the chemical and mounded. The trees were in no way injured from an application of paradichlorobenzene-crude cottonseed oil emulsion spray carrying three-fourths ounce of the chemical to each tree and mounded, but the same treatment of paradichlorobenzene-mineral oil emulsion caused some injury but not so much as from three-fourths ounce of paradichlorobenzene crystals. Paradichlorobenzene gas is given off more rapidly from mineral oil than from cottonseed oil. That may account for the different results from the emulsions carrying three-fourths ounce of the chemical. After four weeks' exposure naphthalene-crude cottonseed oil emulsion carrying one-fourth, one-half, or three-fourths ounce to each tree caused severe injury. The three-fourths ounce dose of paradichlorobenzene crystals severely injured the trees within two weeks. That dosage of naphthalene crystals caused no injury in two weeks but produced severe injury within four weeks.

The dosages of paradichlorobenzene-crude cottonseed oil emulsion carrying one-fourth or three-fourths ounce of the chemical to each tree and mounded killed 100 per cent of the borers, as did the paradichorobenzene-mineral oil emulsion carrying one-half or three-fourths ounce of the chemical per tree and mounded. The dosage carrying one-half ounce of paradichlorobenzene in mineral oil emulsion but not mounded killed only 50 per cent of the borers. Here again better results were

obtained from the emulsion when the trees were mounded after they had been sprayed. The paradichlorobenzene-crude cottonseed oil emulsion carrying one-half ounce of the chemical to each tree and mounded killed only 66.7 per cent of the borers, but here only three borers were involved. Even after a four weeks' exposure all borers were alive in the trees treated with naphthalene-crude cottonseed oil emulsion carrying one-fourth or three-fourths ounce of the chemical to each tree or naphthalene crystals at the rate of three-fourths ounce per tree. The three-fourths ounce dose of paradichlorobenzene crystals killed 100 per cent of the borers in the trees within a period of two weeks.

Six-year-old trees. No injury resulted from the use of either paradichlorobenzene-crude cottonseed oil emulsion or paradichlorobenzene-mineral oil emulsion carrying 1 ounce of the chemical to each tree, whether mounded or not after the spraying, except at one or two areas of about 1 square inch where the spray ran down the tree and puddled. This could be avoided by using less of the emulsion as a carrier for the chemical. Naphthalene-crude cottonseed oil emulsion carrying 1 ounce of the chemical to each tree, whether covered with soil or not, and naphthalene crystals at the rate of 1 ounce per tree produced severe injury to the trees after four weeks' exposure. There was no injury from two weeks' exposure of those materials. There was no injury from two weeks' exposure of paradichlorobenzene crystals at the rate of 1 ounce around each tree.

Paradichlorobenzene-crude cottonseed oil emulsion carrying 1 ounce of the chemical to each tree and mounded gave a 100 per cent control of the borers. The same treatment when the trees were not mounded gave a 75 per cent control. Paradichlorobenzene-mineral oil emulsion carrying 1 ounce of the chemical to each tree and mounded gave a 95.7 per cent control of the borers. The same treatment not mounded gave a 94.7 per cent control. The better results from paradichlorobenzene when applied in a mineral oil emulsion than when applied in a crude cottonsee oil emulsion in experiments where the trees were not mounded after spraying may be due to the fact that paradichlorobenzene gas is liberated more rapidly from mineral oil than from cottonseed oil. All borers were alive in trees treated four weeks previously with naphthalene-crude cottonseed oil emulsion carrying 1 ounce of the chemical to each tree, whether mounded or not, or naphthalene crystals at the rate of 1 ounce per tree. The 57.1 per cent and 20.0 per cent control reported from the naphthalene-crude cottonseed oil emulsion at the end of two weeks was perhaps due to the effect of the crude cottonseed oil, as it has been determined that the oil, when used alone, has some toxicity against borers in

peach trees. As usual, paradichlorobenzene crystals at the rate of 1 ounce for each tree gave a borer mortality of 100 per cent.

Conclusions

Paradichlorobenzene-oil emulsions applied as a spray are apparently the only safe means of controlling the peach borer in one, two, and three-year-old peach trees under conditions in the South. This method of control for older trees is an improvement over the paradichlorobenzene crystal treatment, as it is easier to use and less time is required for the application. Furthermore, it would be more effective than crystals in those districts where borers infest peach-tree roots that are more or less exposed as a result of hillside washing of the soil. Placing several shovelfuls of soil around the tree immediately after treatment increases the effectiveness of the paradichlorobenzene-oil emulsion sprays. As paradichlorobenzene gas is liberated more rapidly from mineral oil than from cottonseed oil, the chance of tree injury is less from paradichlorobenzene-crude cottonseed oil emulsion. For the same reason paradichlorobenzene-mineral oil emulsion should give higher borer mortality if the trees are not mounded after the treatment. Naphthalene-crude cottonseed oil emulsion and naphthalene crystals are injurious to peach trees and not effective against the peach borer.

ORIENTAL FRUIT MOTH[1] STUDIES IN SOUTH CAROLINA—1931[2]

By W. C. Nettles

Abstract

I. A study of the larval parasites of the Oriental fruit moth at Clemson College during 1931 demonstrated the ability of *Macrocentrus ancylivorus* to survive successfully the winter of 1930–1931. Thirty-four and five-tenths per cent of the Oriental fruit moth larvae feeding in twigs were destroyed by parasites during the season. There appeared to be a synchronization between the abundance of parasite and host prior to time of Elberta harvest.

II. Insectary studies indicate that there is a definite relationship beween temperatures at sunset and egg deposition. No eggs were deposited when sunset temperatures were lower than 60 degrees F.; egg deposition was gradually accelerated as temperatures increased from 60 to 75 degrees F.; optimum deposition occurred from 76 to 85 degrees F., and egg deposition was greatly retarded when sunset

[1] *Grapholitha* (*Laspeyresia*) *molesta* Busck.

[2] Technical Contribution No. 24 (New Series) from the South Carolina Agricultural Experiment Station.

temperatures in excess of 85 degrees F. were recorded. Considerable significance is attached to the fact that sunset temperatures were unusually high and egg laying materially reduced during the 12-day period (June 22–July 2) which coincided with one-third of the time during which second brood eggs were being deposited.

III. Life history studies with regard to picking time of Elbertas indicate that overwintering larvae could have developed in late-ripening Elbertas, especially drops or those remaining on trees, and in all varieties ripening thereafter.

For the second consecutive year Elberta peaches escaped severe injury by the Oriental fruit moth following the season of 1929 when severe injury was reported (3) in the Piedmont section of South Carolina. This may be attributed to a number of factors; however, it is believed that two important factors are discernible in the season's data, first, parasitism of twig-infesting larvae by the introduced parasite, *Macrocentrus ancylivorus* Rohwer; second, retardation of egg laying by excessively high temperatures recorded at sunset during late June and early July.

I. Parasitism of Twig Infesting Larvae

Conditions and Locality of Study.—The study was made from larvae collected in the Clemson College orchard. During the summer of 1930 *Macrocentrus ancylivorus* Rohwer was secured from southern New Jersey (2) and liberated in this orchard. No liberations were made in this particular orchard during 1931. A doubt was felt as to the ability of the parasite to survive our winters, not on account of temperatures but on account of the absence of a certain insect in which this parasite overwinters in other localities; namely, the strawberry leaf roller, *Ancylis comptana* Froel.

Methods.—Throughout the length of the larval feeding period injured twigs were clipped from trees which had not yet reached bearing age. The twigs were carefully examined to ascertain the presence or absence of larvae. The period of orchard collections extended from May 2 to September 8. The collections were made at more or less regular intervals which varied from five to ten days. Each collection extended over a two-hour period.

The infested twigs were placed in large ice tea glasses in the bottom of which a small amount of moist sand had been added. Small, green apples were also supplied to furnish food for the larvae as they left the twigs. The top of the glass was covered by a strip of cloth held in place by a stout rubber band.

Examinations were made daily for cocooning larvae, each of which was placed in a glass vial. The larvae were observed daily and the date on which pupation occurred or on which they were visibly destroyed

was recorded. In the case of parasites the date of emergence was also obtained.

In this report the only larvae considered are those killed by parasites or which pupated.

The difference between *Macrocentrus ancylivorus* and *Macrocentrus delicatus* was determined by the writer using characters published by Driggers and Pepper (3). All determinations are subject to verification by workers in the United States Bureau of Entomology.[2]

TABLE 1. PARASITISM OF TWIG-INFESTING LARVAE. CLEMSON COLLEGE ORCHARD, 1931

Date collected	No. larvae	Larvae pupating	No. parasitized	% parasitized
5/2	24	8	0	0
5/7	46	14	0	0
5/13	46	26	0	0
5/23	86	56	0	0
5/29	120	64	0	0
6/5	147	69	10	12.7
6/11	124	66	5	7.0
6/19	205	86	21	19.6
6/26	184	91	14	13.3
7/3	168	91	0	0
7/10	193	27	60	68.9
7/17	308	38	115	75.2
7/25	248	54	52	49.1
7/31	105	2	29	93.5
8/7	64	3	12	80.8
8/17	31	0	13	100.0
8/25	49	1	16	94.1
8/31	41	0	16	100.0
9/8	4	0	4	100.0
Total		696	367	

CONCLUSIONS.—It appears that we have a clear demonstration of the ability of *Macrocentrus ancylivorus* to survive the winter in South Carolina. Alden (1) also states, "This parasite was recovered in the spring (at Cornelia, Georgia) from colonies placed out in 1930, showing that it survived the winter and had successfully established itself in the state."

Figure 44 also indicates that:

1. There was a lack of larval parasitism prior to June 5.
2. When twig infestation was greatest, parasitism was also very high.
3. As the population of Oriental fruit moth larvae decreased, parasitism ran unusually high.

It is significant to note that all but about one and seven-tenths per

[2]Since the preparation of this manuscript, a letter from Dr. H. W. Allen has been received which confirms the determinations of the writer for all practical purposes.

cent of the parasitism can be attributed to *Macrocentrus ancylivorus* Rohwer, and that for the season 34.5 per cent of twig-feeding larvae were destroyed. *Macrocentrus delicatus* was reared in exceedingly small numbers.

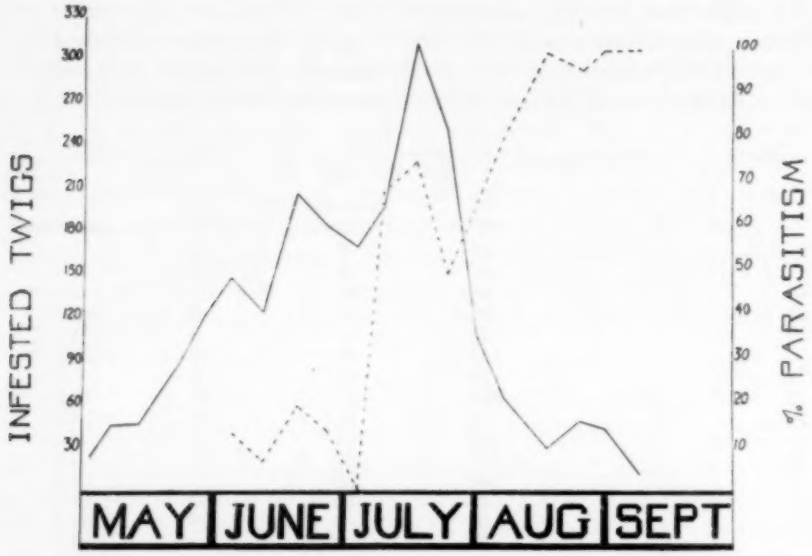


Fig. 44 shows the percentage parasitism and larval population graphically. The dotted line shows parasitism expressed in percentages and the solid line shows the larval population expressed in number of infested twigs collected in two hours.

II. Relationship of Sunset Temperatures to Oriental Fruit Moth Egg Deposition

Object.—The object of this section is to show the relationship between egg deposition of Oriental fruit moths and sunset temperatures.

Method.—These data are part of the life history studies and were conducted throughout the season. For a more complete discussion and illustration of methods the reader is referred to South Carolina Experiment Station Bulletin 278—"Biological Studies of The Oriental Fruit Moth 1930." The number of eggs laid per moth is not based on its entire life but over a period of eight days when the greater portion of the eggs are deposited, and allows a two-day preoviposition period.

Stearns and Neiswander (7) state, "Insectary records show that heaviest oviposition commonly occurs during the evening." Observations by the writer also indicate that most of the eggs are laid about sunset when the moths are flying most actively; therefore, the tempera-

tures recorded at this time may be considered as an index to any relationship which might exist between temperature and egg deposition.

The temperature was recorded by a hydrothermograph. The time of sunset was furnished by the United States Weather Bureau for Clemson College, South Carolina.

The writer presents this section with the hope that other entomologists who are better equipped and are working on the same problem will verify these observations through laboratory tests under controlled conditions.

Two questions which must be solved before one can state definitely that the same relationship of temperature to egg deposition exists in the orchards are:

1. How does the temperature in an oviposition jar compare with that of the surrounding air?

2. How does the temperature in the orchard compare with that recorded in the insectary?

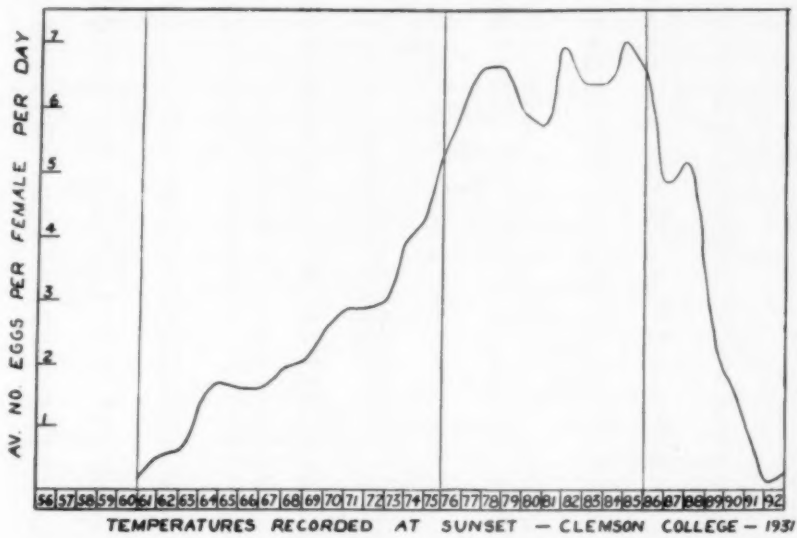


Fig. 45. Showing relationship between sunset temperature and egg deposition

PRESENTATION OF DATA.—Table 2 shows the number of actively laying moths on test, number of eggs laid by the moths, and temperatures recorded at the time of sunset. Figure 45 is constructed from the data presented in Table 2 by using a five-degree moving average to calculate the number of eggs laid per moth at given temperatures ranging

TABLE 2. SHOWING NUMBER EGGS LAID BY MOTHS ON TEST AND SUNSET TEMPERATURES

Date	No. moths	No. eggs	Sun-set temp.	Date	No. moths	No. eggs	Sun-set temp.	Date	No. moths	No. eggs	Sun-set temp.
4/3	4	6	67	6/6	18	71	86	7/28	9	106	76
4/4	4	17	62	6/7	28	41	78	7/29	11	33	86
4/5	4	0	47	6/8	28	21	70	7/30	7	103	88
4/6	17	0	47	6/9	33	52	74	7/31	6	38	82
4/7	17	0	61	6/10	36	129	80	8/1	5	22	80
4/8	12	114	70	6/11	34	35	84	8/2	8	21	81
4/9	22	117	72	6/12	34	119	75	8/3	8	0	88
4/10	21	45	72	6/13	29	92	76	8/4	18	245	84
4/11	21	0	60	6/14	40	160	70	8/5	16	138	78
4/12	49	21	67	6/15	26	197	80	8/6	15	74	76
4/13	44	163	69	6/16	31	60	72	8/7	23	212	78
4/14	36	75	73	6/17	30	269	82	8/8	23	301	85
4/15	36	0	70	6/18	26	85	84	8/9	35	286	86
4/16	39	39	72	6/19	29	36	82	8/10	31	255	80
4/17	25	0	72	6/20	25	74	88	8/11	31	68	70
4/18	34	0	59	6/21	19	0	82	8/12	31	45	68
4/19	47	128	71	6/22	14	0	87	8/13	31	253	76
4/20	27	18	66	6/23	24	15	82	8/14	41	234	71
4/21	27	132	72	6/24	26	21	86	8/15	32	194	78
4/22	24	0	57	6/25	23	16	84	8/16	31	370	75
4/23	24	5	64	6/26	23	0	88	8/17	18	179	80
4/24	24	9	60	6/27	30	0	92	8/18	17	99	77
4/25	30	0	62	6/28	24	15	92	8/19	15	88	83
4/26	21	71	66	6/29	33	0	90	8/20	21	158	78
4/27	18	0	64	6/30	32	9	84	8/21	21	115	76
4/28	18	0	66	7/1	29	0	88	8/22	14	0	65
4/29	18	1	75	7/2	22	0	90	8/23	22	98	70
4/30	25	24	73	7/3	17	29	85	8/24	—	—	—
5/1	35	29	62	7/4	17	9	74	8/25	22	90	78
5/2	35	127	70	7/5	23	108	74	8/26	28	218	80
5/3	29	29	76	7/6	28	120	82	8/27	28	162	78
5/4	28	0	67	7/7	18	88	86	8/28	16	172	82
5/5	16	0	56	7/8	31	294	86	8/29	28	293	76
5/6	14	0	64	7/9	40	228	74	8/30	28	188	78
5/7	14	31	66	7/10	35	460	80	8/31	18	81	78
5/8	10	10	69	7/11	43	420	77	9/1	18	83	84
5/9	5	2	64	7/12	40	578	83	9/2	17	106	78
5/10	5	0	70	7/13	33	301	80	9/3	14	110	76
5/11	5	0	71	7/14	42	162	84	9/4	17	188	80
5/12	5	50	62	7/15	42	317	77	9/5	17	77	85
5/13	5	11	64	7/16	28	177	88	9/6	6	86	86
5/14	5	23	66	7/17	27	211	87	9/7	6	36	84
5/15	5	0	64	7/18	27	253	85	9/8	6	0	78
5/16	5	43	65	7/19	20	131	79	9/9	6	8	82
5/17–5/31	Moths on test but too few to be recorded here.			7/20	19	97	82	9/10	6	4	84
				7/21	19	123	70	9/11	3	53	80
				7/22	13	166	83	9/12	6	65	82
				7/23	11	102	82	9/13	6	56	75
6/1	6	0	74	7/24	9	71	82	9/14	6	34	74
6/2	6	0	78	7/25	9	101	80	9/15	6	14	76
6/3	9	44	84	7/26	9	68	76	9/16	6	27	80*
6/4	9	3	87	7/27	8	65	83				
6/5	18	73	85								

*Eggs laid later in season, but number of moths emerging made data scant.

from 47 to 92 degrees F. Since no eggs were laid at temperatures lower than 60 degrees F., the writer decided to use 60 degrees F. as the starting point for the average.

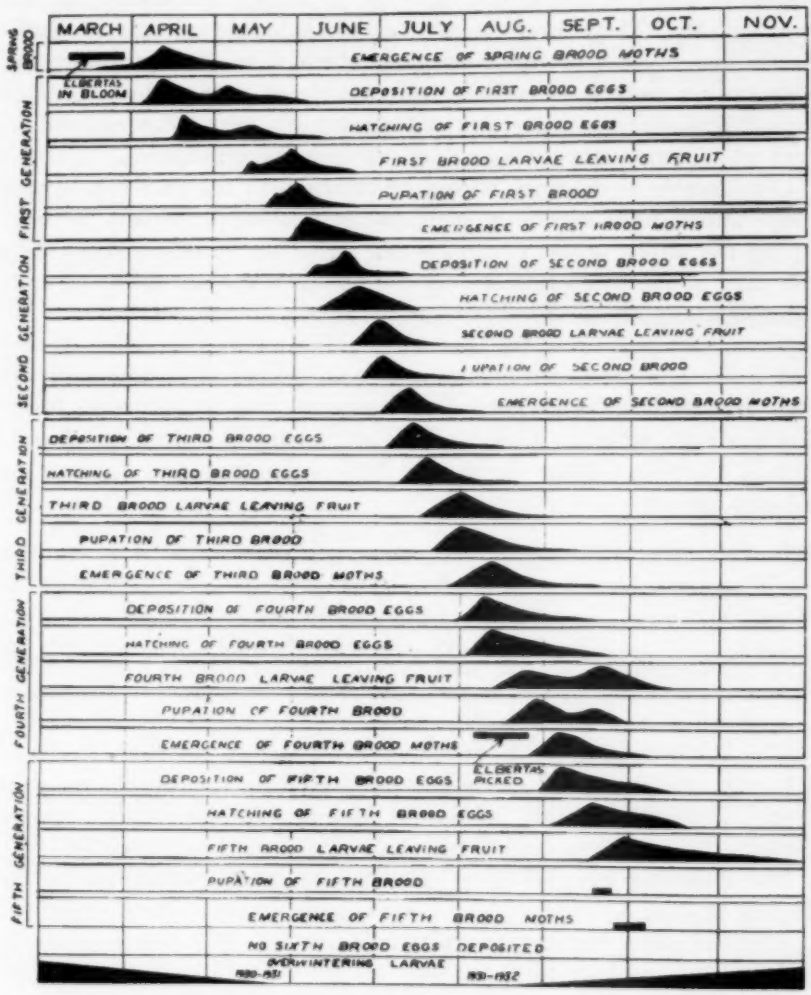


Fig. 46. Showing life history during 1931 with regard to bloom and picking time of Elbertas

RESULTS.—Egg laying rapidly decreased when sunset temperatures exceeding 85 degrees F. were recorded. This corresponds with similar observations by Garman (6) who is quoted here, "If very hot, 90–100

degrees, the moths suffer and many die without laying." It appears that the optimum conditions are found between 76 and 85 degrees F.

Before Elberta harvest a total of 115 days passed when moths were present in numbers and should have laid if temperature conditions had been suitable. There were seven days when temperatures were sufficiently low to prevent egg deposition; there were 19 days when the temperatures were sufficiently high to retard egg laying; there were 43 days during which optimum sunset temperatures were recorded; and 46 days when temperatures lower than optimum were recorded.

Considerable significance should be attached to the fact that sunset temperatures were unusually high and egg laying materially reduced during the 12-day period (June 22–July 2). This period coincided with one-third of the time (June 4–July 10) during which second-brood eggs were being deposited. See life history diagram, Figure 46.

CONCLUSIONS.—From the insectary studies reported here, it appears that temperature plays an important role in determining the number of eggs deposited by the Oriental fruit moth and that temperatures below and above the optimum were recorded during the period of egg deposition at Clemson College during the 1931 season prior to the time of Elberta harvest.

III. THE LIFE HISTORY OF THE ORIENTAL FRUIT MOTH IN SOUTH CAROLINA DURING 1931 WITH REGARD TO BLOOMING PERIOD AND PICKING TIME OF ELBERTAS

METHOD OF STUDY.—The life history studies were made in the usual manner. For a description and illustrations of methods used the reader is referred to a previous publication (5).

The line indicating the bloom period begins when the first blooms of Elbertas were noted and extends to the time when the last blooms were seen. The line indicating the time of picking Elbertas covers a similar period. Both of these periods are shown graphically in Figure 46.

The following data will give some idea of the magnitude of the life history studies:

Deposition and hatching of 14,799 eggs.

Leaving of fruit of 1,921 larvae.

Pupation of 1,518 larvae.

Emergence of 2,247 moths.

RESULTS.—Elberta peaches had completed blooming prior to the time that the peak of emergence of the spring brood occurred and were in full bloom (March 19) at the time the first moths emerged (March 18).

Elberta peaches were picked at approximately the time of hatching

of fourth-brood eggs and after the majority of third-brood larvae had left the fruit.

The first overwintering larvae hatched four days prior to the picking of the last Elberta peaches.

DISCUSSION.—The fact that the full bloom of peach and emergence of the first moths of the spring brood coincided is in accord with the findings of Stearns and Peterson (6) in New Jersey.

It was possible for overwintering larvae to develop in Elbertas which ripened late, especially drops, at Clemson College, South Carolina during 1931.

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SEX DIFFERENTIATION OF ADULTS OF *CONOTRACHELUS NENUPHAR*

By J. R. THOMSON, JR., *U. S. Peach Insect Laboratory, Fort Valley, Georgia*

Inability of workers at this and other laboratories to determine the sex of adults of the plum curculio (*Conotrachelus nenuphar* Hbst.) without dissection has handicapped certain phases of biological studies on this insect. To find some outstanding or clearly defined difference in the external anatomy of male and female is desirable. At the suggestion of Mr. Oliver I. Snapp and with his help, therefore, the writer has attempted to work out or discover some simple method whereby the male and the female adult of *Conotrachelus nenuphar* can be easily differentiated.

Differentiating the sexes of *Conotrachelus nenuphar* adults is somewhat difficult owing to the very close resemblance of male and female in habit, body size, body contours, appendages, and color pattern. Generally

Fig. 47.—Posterior end of abdomen, dorsal view.

speaking, the males average slightly smaller than the females but there is the problem of size variation among the males themselves from small to large and, of course, the same condition occurs among the females, and this excludes the size factor for use in accurate sex determination.

The method commonly used by workers in differentiating the sexes,

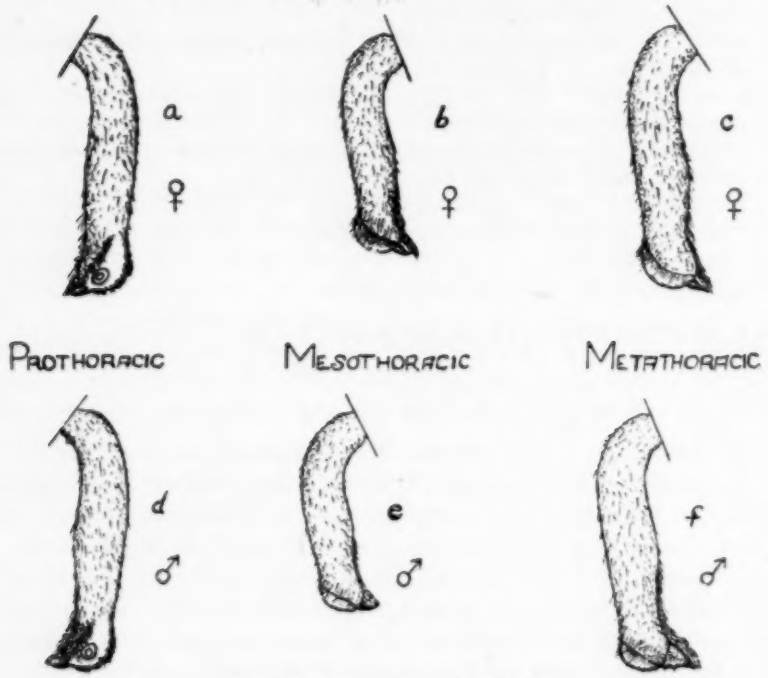

Fig. 48.—Structure of tibiae.

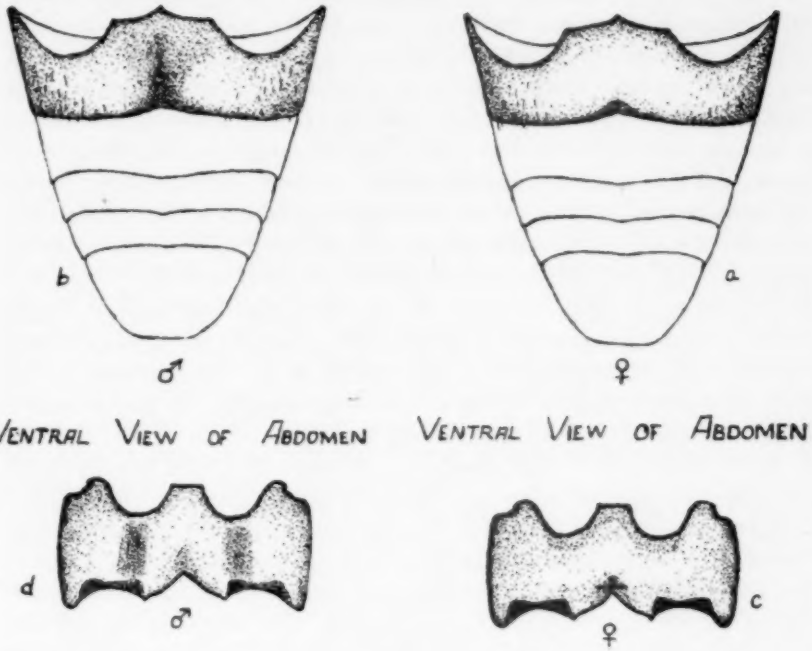

Fig. 49.—Structure of the ventral abdominal segments and metathoracic sternite.

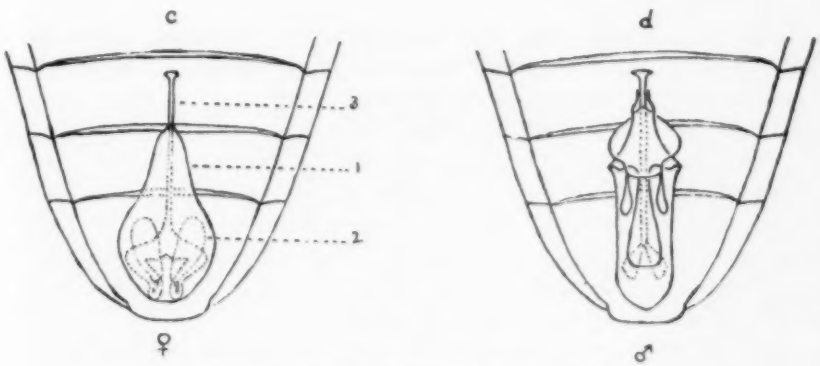

Fig. 50.—Dorsal view of genital organs and penis.

and one that is accurate barring any mistakes that nature might make, is that of inducing copulation. When it is desired to pair off or separate the sexes in a group of several beetles, they are placed in a cage and time given for individuals to begin copulating. When copulation takes place the relative position, of course, designates which is male and which is female. With this method nature has to be given time to take its course, and this is not always convenient for one desiring quick results.

A microscopic study of the external anatomy of adult beetles of *Conotrachelus nenuphar*, in search of sex differences that would accurately designate male and female beetles, resulted in four findings. One was the difference in size and shape of the supra-anal plates of male and female as shown in Figure 47, *a* and *b*. The posterior end of the abdomen is covered, of course, by the elytra, which makes examination of the supra-anal plates of live beetles not so easy. Another finding is an enlarged and modified tibial spur on the metathoracic leg of the male, as shown in Figure 48, *f*, that clearly sets it apart from the female. This enlarged and modified tibial spur is easily recognized with the aid of a microscope. There is a small tibial spur on both prothoracic and mesothoracic legs of the male (Fgure 48, *d* and *e*) that is similiar in size and shape to the tibial spur on the prothoracic, mesothoracic and metathoracic legs of the female (Figure 48, *a*, *b*, and *c*). Probably the clearest and most easily noticed difference, however, is that found in comparing the first ventral abdominal segment of male and female. The first visible sternite at the base of the abdomen of the female is slightly convex while that of the male is more or less impressed, (Figure 49, *a* and *b*). On comparing the metathoracic sternite of male and female, Figure 49, *c* and *d*, there is found in the male a broad, well defined groove extending from the inner edge of the posterior coxa toward the midcoxa which is not present in the female.

Figure 50, *c*, which is entirely diagrammatical in nature, shows the relative position only of genital and oviposition organs of the female viewed dorsally on removal of the abdominal tergites—1, a clear, somewhat transparent organ, half pear shaped with convex side dorsal; 2, two very thin chitinous plates joined to each other by thin membranous tissue and lying between 1 and 3; 3, an andiron-shaped figure lying beneath 2, the stem and shoulders of which are heavy chitin while the two arms become very thin near and at the apexes. Figure 50, *d*, shows diagrammatically the relative position only of the penis in the male viewed dorsally on removal of the abdominal tergites.

A PROGRESS REPORT ON FEEDING TESTS AND SPRAYING AND DUSTING EXPERIMENTS FOR THE CONTROL OF THE PLUM CURCULIO

By OLIVER I. SNAPP and J. R. THOMSON, *U. S. Peach Insect Laboratory, Fort Valley, Georgia*

ABSTRACT

Feeding tests showed potassium fluosilicate at the rate of 2 pounds to 50 gallons of water to be a little more toxic to the plum curculio (*Conotrachelus nenuphar* Hbst.) than lead arsenate at the rate of 1 pound to 50 gallons of water. Furthermore, potassium fluosilicate was somewhat more toxic to the plum curculio than barium fluosilicate or cryolite. Wettable sulphur increased the toxicity of fluosilicate as insecticides for the curculio. The toxicity of those insecticides was considerably reduced when they were used at the rate of ¼ or ½ pound to 50 gallons of water. Calcium monosulphide greatly decreased the toxicity of the potassium fluosilicate, which may have been due to its repellent action. Lead arsenate dusts were not so toxic as the spray. Copper carbonate, wettable sulphur, and zinc sulphate-lime spray, when used alone, were not toxic to the plum curculio.

Four applications of potassium fluosilicate at the rate of 2 pounds to 50 gallons with and without wettable sulphur, caused no injury to foliage, fruit or budwood of peach trees. Four applications of barium fluosilicate or cryolite at the rate of 2 pounds to 50 gallons of water caused no injury to the foliage, fruit, or budwood. Four applications of lead arsenate at the rate of 1 pound to 50 gallons of water with lime burned 2.5 per cent of the fruit and caused moderate to heavy foliage injury with considerable defoliation and occasional budwood injury. Four applications of lead arsenate of the same strength with zinc-lime spray burned 9.2 per cent of the fruit and caused light to moderate foliage injury with very little defoliation and no budwood injury.

Three applications of dust containing 10 per cent lead arsenate caused moderate injury to the foliage with considerable defoliation, but no budwood injury. Three applications of lead arsenate spray at the rate of 1 pound to 50 gallons of water with lime caused moderate foliage injury but not as much defoliation as the 10 per cent dust and no budwood injury. There was practically no foliage injury from three applications of dust containing 5 per cent lead arsenate or from three applications of potassium fluosilicate spray.

Of many fluosilicates and arsenicals which were tested on the plum curculio, *Conotrachelus nenuphar* Herbst, at the Fort Valley, Ga., laboratory in 1927, sodium fluosilicate without lime, both as dust and at the rate of 2 pounds to 50 gallons of water, was reported[1] to be the most toxic to that insect. It was found, however, that the insecticide without lime was very toxic to peach foliage and fruit. While lime corrected the burning effect of sodium fluosilicate, it largely destroyed its toxicity as

[1]Snapp, Oliver I. A Preliminary Report on the Toxic Value of Fluosilicates and Arsenicals as Tested on the Plum Curculio. Jour. Econ. Ent. 21: 175–177. 1928.

an insecticide for the plum curculio. Therefore, during the seasons of 1928 and 1929 field experiments with a number of fluosilicates without lime were conducted in an effort to find one which caused no injury to peach fruit or foliage. Potassium fluosilicate without lime proved to be the safest during those seasons, and as a result a number of feeding tests were conducted in 1930 to determine the toxicity of that fluosilicate as an insecticide for the plum curculio.

FEEDING TESTS IN 1930. Each of the eighteen feeding tests of 1930 was conducted in a 6-inch by 12-inch battery jar. Moist sand was placed in the bottom of the jars, and the tops were covered with thin cheesecloth. The receptacles for holding in water the peach twigs containing fruit and foliage were small-mouth bottles imbedded in the moist sand. To prevent the beetles from drowning the stems of the peach twigs were wrapped with cotton so as to fit tightly into the neck of the bottles. A hand sprayer, which produced a good mist, was employed in applying the insecticides, and the fruit and foliage on each twig used in the tests received a thorough application. The spray was allowed to dry before the twigs were placed in the cages containing the plum curculios. All beetles used had emerged from the soil on the day that the tests were started and had done no previous feeding. The jars were kept in a shaded insectary, and the thin cheesecloth tops provided ventilation. Observations for curculio mortality in each jar were made daily.

According to these tests potassium fluosilicate at the rate of 2 pounds to 50 gallons of water was a little more toxic to the plum curculio than lead arsenate at the rate of 1 pound to 50 gallons of water plus 4 pounds of hydrated lime. Potassium fluosilicate at the rate of 1 pound to 50 gallons of water was nearly as toxic as lead arsenate at the same rate. Wettable sulphur increased the toxicity of potassium fluosilicate as an insecticide for the plum curculio. Calcium monosulphide materially lowered the toxicity of potassium fluosilicate, which may have been due to its repellent action. There was very little feeding on the foliage or fruit sprayed with that combination.

FEEDING TESTS OF 1931. Since potassium fluosilicate was found to be so toxic to the plum curculio in the feeding tests of 1930, the work was continued the following year to include other fluosilicates. The toxic values of these were compared with lead arsenate spray and dust as insecticides for the plum curculio. Sixty-one tests were conducted, and the method employed was the same as that used in 1930. The dust was applied with a hand duster. All beetles used had emerged from the soil on the day that the tests were started and had done no previous feeding.

Peach foliage and fruit were used in each test conducted in June.

Most of the curculios prefer fruit to foliage as food, and feeding takes place mostly on the inside of the fruit after a sufficient amount of the outside is eaten away to permit entrance of the beetles. Therefore, after small holes are made in the fruit the insects feed on untreated food. The low and varying mortality from some of the insecticides tested during June may have been due to the feeding of some beetles on the inside of the peaches.

Only peach foliage was used in each test conducted in July. The results of those tests showed that potassium fluosilicate was the most toxic of the fluosilicates to the curculio, although barium fluosilicate was almost as toxic. Cryolite was the least toxic of the three fluorine compounds. Potassium fluosilicate at the rate of 2 pounds to 50 gallons of water was a little more toxic to the curculio than lead arsenate at the rate of 1 pound to 50 gallons of water, although both gave a 100 per cent mortality at the end of 6 days, as did barium fluosilicate. Lead arsenate dusts were not so toxic as the spray.

The results of the June tests indicate that wettable sulphur increases the toxicity of fluosilicates as insecticides for the plum curculio. That was also reported from the results of 1930. The toxicity of those insecticides was considerably reduced when they were used at the rate of ¼, ½, or 1 pound instead of 2 pounds to 50 gallons of water. Copper carbonate, wettable sulphur, and zinc sulphate-lime spray, when used alone, were not toxic to the plum curculio.

Spray Experiments to Determine the Effect of Fluorine Compounds and Lead Arsenate on Peach Foliage, Fruit, and Budwood

Tests in 1930. In 1930 potassium fluosilicate, 2 pounds in 50 gallons of water, was applied to small plats of Elberta peach trees four times during the season. In one of these plats wettable sulphur, 3 pounds in 50 gallons of water, was added to the last two applications.

No injury to foliage, fruit, or budwood developed from these applications.

Tests in 1931. Similar tests were conducted in 1931 in a small orchard which is maintained for experimental work. Applications were made when 75 per cent of the petals had fallen, when the calyces were shedding, two weeks after the shedding of the calyces, and four weeks before harvest. The tests included barium fluosilcate and cryolite, with wettable sulphur, lead arsenate with hydrated lime and wettable sulphur, and lead arsenate with the addition of zinc sulphate and hydrated lime,

throughout the season. The concentrations used and the injury which resulted from the applications are recorded in Table 1.

TABLE 1. TESTS TO DETERMINE THE EFFECT OF FLUORINE COMPOUNDS AND LEAD ARSENATE ON PEACH FOLIAGE, FRUIT, AND BUDWOOD. FORT VALLEY, GA., 1931. (FOUR APPLICATIONS MADE)

Plat No.	Material	Quantity in 50 gallons	Injury to— Foliage	Budwood	Fruit
1	Barium fluosilicate[1]	2 lbs.	None	None	None
2	Do.[1]	1 lb.	Do.	Do.	Do.
3	Cryolite [1]	2 lbs.	Do.	Do.	Do.
4	Do.[1]	1 lb.	Do.	Do.	Do.
5	Lead arsenate with hydrated lime and wettable sulfur[1], [2]	1 lb.	Moderate to heavy with considerable defoliation	Occasional	2.5 per cent of fruit showing burn
6	Lead arsenate with zinc sulphate and hydrated lime[3]	1 lb.	Light to moderate with very little defoliation	None	9.2 per cent of fruit showing burn
7	No treatment	——	—	—	—

[1]Plus wettable sulphur, 3 lbs. in 50 gallons in 3rd and 4th applications.
[2]Plus hydrated lime, 4 lbs. in 50 gallons in 1st and 2nd applications.
[3]Plus zinc sulphate 4 lbs., hydrated lime 4 lbs. in 50 gallons of water with each application.

In addition, another series of tests was conducted on Elberta trees in an eight-year-old commercial orchard, in plats containing approximately 300 trees each. The tests included potassium fluosilicate as compared with the standard lead arsenate liquid treatment, as well as two dusted plats, in one of which the dust contained 5 per cent of lead arsenate, and in the other of which it contained 10 per cent of lead arsenate. The spray program followed was a modification of the standard schedule which was recommended for the Fort Valley district during the

TABLE 2. INJURY NOTES; LARGE-SCALE PEACH SPRAYING AND DUSTING TESTS, FORT VALLEY, GA., 1931 (ELBERTA VARIETY, 3 APPLICATIONS MADE)[1]

Plat No.	Material	Foliage injury
1	Dust-lead arsenate 10%, with hydrated lime 90% in 1st application; hydrated lime 10%, sulphur 80% in 2nd and 3rd applications	Moderate, considerable defoliation
2	Liquid spray, lead arsenate 1 lb. in 50 gallons, with hydrated lime 4 lbs. in 50 gallons, 1st application; with self-boiled lime-sulphur in 2nd and 3rd applications	Moderate foliage injury, some defoliation but less than in Plat 1
3	Liquid spray, potassium fluosilicate, 2 lbs. in 50 gallons, with wettable sulphur, 3 lbs. in 50 gallons in 2nd and 3rd applications	Practically none
4	Dust-lead arsenate 5%, with hydrated lime 95% in 1st application; hydrated lime 15%, sulphur 80% in 2nd and 3rd applications	Practically none

[1]Budwood and fruit uninjured throughout tests.

1931 season. The usual petal-fall application was omitted because the curculio adults were abnormally late in reaching the orchards. The schedule therefore included three applications beginning with the shuck-fall spray.

None of the four plats averaged more than 2 per cent of curculio injury for the season, and because of the abnormally low level of curculio infestation in the Fort Valley section in 1931, the results obtained are of doubtful significance and the detailed records will not be given here. The records as to foliage injury, however, may be of some interest, and these are shown in Table 2.

THE ROCKING MOVEMENTS OF BEES[1]

By ERWIN C. ALFONSUS, *Beekeeping Department, University of Wisconsin, Madison, Wisc.*

ABSTRACT

Rocking movements are performed by young bees. The purpose of these movements is the cleansing and polishing of the interior of the hive. The same operations are also performed on exterior parts of the hive to provide a clean clustering space. The liking of bees for smooth surfaces seems to cause this mechanical cleansing process.

This peculiar activity of the honeybee attracted the attention of many early observers. It has been described in bee magazines of every country where honeybees are kept, regardless of the race of bees. The descriptions of the procedure are all quite similar, except for the question of whether or not the proboscis is involved.

Dönhoff (1) believes that these movements are the results of a playing instinct in the bees. The same opinion about bees engaging in perpendicular movements is forwarded by Schmid and Kleine (2). Mehring (3) does not believe in a playing instinct and states that he observed the application of a transparent film of wax to soiled places within the hive by using the tongue in a brush-like manner. Kleine (4) doubts Mehring's observation since the bee has no means of producing wax in the cephalic region or in the alimentary canal. He admits that there must be a purpose to this rocking and believes it to be a scraping process to remove fungi and lichen from the weather exposed parts of the bee hive. Mehring (5) replies that he is certain about his above mentioned observation but it is up to others to find the organs related to such a secretion.

[1]Contribution from the Department of Economic Entomology, University of Wisconsin, Madison, Wis.

Buttel-Reepen (6) also believes this conspicuous activity to be an expression of a playing impulse.

Hajdak (7) explains the procedure as a mechanical cleaning process by which the mandibles and the tarsi of the front legs serve as scrapers while the front legs are also used to clean the mandibles. He observed rocking bees not only at the entrance but throughout the hive but did not observe the use of the tongue nor the application of any secretion.

Vahan (8) observed bees performing these "rhythmic" movements, with their tongues half unfolded on the alighting board and inside the hive. The hind legs of a rocking bee cling on the alighting board while the abdomen is slightly downward bent. The thorax with the second pair of legs moves steadily to and fro. Front legs and antennae are moved vigorously and the head is bent forward. The bees seem to be looking for or petting something invisible on the alighting board. The wings are slightly opened or kept in a resting position.

These movements were not observed during a rapid honey flow. Vahan cannot explain this phenomena, neither does literature provide a satisfactory answer. He asks for someone to explain this puzzling behavior. Morgenthaler (9) in a literature study reviews the most of the above mentioned citations. In relation to Mehring's observation he refers to the recent discovery of Philipp (10) concerning the coating of all interior parts of the hive, including the combs, with a substance which he named "Pollen-balsam." This substance is supposed to be derived from the oily coat of pollen grains as a by-product of pollen digestion. The undigestible coat of pollen is separated after the crushing of the pollen grains in the proventriculus, returns to the mouth and is painted upon subjects with the tongue. Philipp, however, does not mention any rocking during this painting process. For anatomical reasons, however, Evenius (11) shows the untenability of Philipp's theory.

As far as the chemical properties of the pollen coat are concerned, Zetzsche (12) found the coating to consist of two layers, an inner layer of cellulose and a comparatively much larger outer layer of "Pollenin." This is an elastic substance not known to occur elsewhere in the plant kingdom and belongs to the polymerised terpenes. Related substances constitute the principle part of essential oils.

Morgenthaler (9) received information from Zetzsche concerning the probability of Philipp's theory. Zetzsche is convinced of the impossibility of the bee being able to apply pollenin in a manner as pollen balsam is supposed to be distributed, since the bee might not have an agent at its disposal to liquify the extremely tough and hardly soluble pollenin.

As far as the mechanics of pollen digestion are concerned, Whitcomb

and Wilson (13) have clearly shown that no grinding or crushing of pollen grains takes place in any part of the alimentary canal. As the pollen reaches the hind intestine, the grains are nearly all empty. Only the pollen coats which retain the original shape of the grains, except in the case of squash pollen where collapsing occurs, are left.

Miss Betts (14) after reviewing Morgenthaler's paper, tells about the rocking movements of a young bee after she had filled her sac from the experimental syrup supply. Miss Betts suggests tentatively that it is not merely play, it might just possibly be the reaction of a young bee, at the honey ripener age. The following questions are presented: Do the rocking movements serve to propel the contents of the honey-sac up and down the oesophagus, perhaps to mix it well with the added enzymes? And is the exuding substance merely unripe honey?

OBSERVATIONS. The past season, summer 1931, bees engaging in rocking movements were observed and studied several times at the University Apiary and in two other apiaries. To obtain a better picture of the action of individual bees a hand lens was used and individual bees were marked with paint dots on the thorax.

A rocking bee behaves exactly in the manner as described by Vahan (8) only that the bottom of the mandibles is in direct contact with the supporting surface. The movement extends over a distance of 3 to 4 millimeters. During the movement to and fro the mandibles slide over the surface and they are continuous and rapidly closed and opened, as if the bee was chewing something off the surface. At the same time the tips of the antennae also touch the surface and a vibration-like movement of the antennae is noticeable. The front legs also take an active part in the movements. The tarsi slide over the surface being brought closer together as the bee moves forward and taken apart again as the bee retreats. These legs also undergo a vibration or trembling very similar to the action of the antennae. The second pair of legs and the hind legs serve as a body support and they are not moved unless the bee changes its position. In none of the observed cases which occurred throughout the season was it observed that the proboscis was engaged in any way. As a rule the proboscis of rocking bees, regardless of the place where rocking occurs, inside the hive, on the alighting board or the front piece of the hive, is in a resting position, folded under the head.

The rocking of a single bee is often interrupted by cleaning operations. The head and the antennae are cleaned with the front legs. The front legs are cleaned with the second pair of legs and these again are cleaned on the inner surface of the metatarsi of the hind legs.

Bees have been observed to engage in continuous rocking, including a

few swift cleaning operations, from 10 to 35 minutes. They rock until they disappear inside the hive or often take off for a flight. They stay in the air from 2 to 5 minutes, return and again start to rock or enter the hive. Bees which entered the hive are frequently observed to appear back among the rockers.

Rocking bees from various places inside the hive were caught, or returning from a flight and taken to the laboratory. A dissection under the binocular microscope showed that in all cases, without exception, only a very limited amount of liquid was found in the honey sac.

Rocking movements take place on two occasions: 1. On days when there is no honey flow or at most only a light flow, inside and outside the hive. 2. On days after heavy rains, when a high temperature forces strong colonies to cluster about the entrance in the evening, the bees rock on exposed parts of the hive, regardless of flow conditions.

The splashing drops of a heavy rainfall soil the hive around the entrance especially the front piece. As soon as the hive is dry and the sun shines the rocking starts. The space on which rocking occurs is identical with the needed clustering space. A sheet of paper was laid upon the entrance and on this paper the material collected, which was scraped from the front piece by rocking bees. It consisted entirely of soil particles and dead plant material. Extremely small particles do not collect on the paper since the continuous draft caused by fanning bees blows them off immediately. The rocking is carried on until the necessary clustering space is snowy white and smooth. It is quite possible that on unpainted hives fungi and lichen are also removed by the rocking bees. The application of muddy water to the front piece or an artificial soiling also produces the rocking movement. Rocking has been observed to continue as long as 3 and 4 days until the clustering space appeared speckless. A sheet of paper covering the entire bottomboard inserted in a colony where interior rocking occurred did not collect anything else but the usual hive refuse, lost heaps of pollen and particles of brood cappings. However, since the symptoms of rocking bees inside the hive are exactly the same as those of bees rocking about the entrance it is certain that the same purpose is fulfilled in both places. It is evident that the rocking movements represent a mechanical cleaning process, engaging the mandibles as scrapers and polishers, while the antennae and front tarsi with their tactile organs serve to discover rough or soiled places and also check the result of the smoothing process.

The number of bees engaging in rocking movements varies greatly. Upon opening a colony of bees where rocking inside the hive occurs or looking at such a colony through the window of an observation hive, one

believes at the first impression that all the bees are rocking but a closer examination will show that only a minority of bees are busy with rocking, the other bees being engaged in the usual hive duties. When rocking occurs on the outside of the hive the number of bees is determined by the size of the needed clustering space on the front piece and the alighting board. As many as approximately 250 bees were observed rocking on the outside of a hive. The first impression is as if the bees were arranged in rows performing a rhythmic dance but a closer study reveals that no definite arrangement takes place. There isn't even the slightest sign of a regular arrangement except for the fact that all bees while rocking, face the entrance. A general rhythm could not be observed. The movements of a single bee are quite regular, interrupted only by cleaning processes, but there is no harmony whatever with the rhythm of the surrounding bees. A rocking bee does not seem to pay the slightest attention to its environment. As far as the age of the rocking workers is concerned, it can be observed that they all exhibit a uniform appearance, caused by an undamaged pubescence as it is only characteristic for young bees. Presumably cleaning by rocking movements is part of the duties of young bees before they take up collecting.

Summary and Conclusions

1. The rocking movements of bees represent a mechanical cleaning process.
2. No application of a liquid of any kind accompanies the movement.
3. It occurs inside and outside the hive only during periods of inactivity, outside the hive to provide a clean clustering space regardless of flow conditions.
4. The rocking movement is apparently performed by young bees.

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THE TEMPERATURE RELATIONSHIPS OF THE HONEYBEE CLUSTER UNDER CONTROLLED EXTERNAL TEMPERATURE CONDITIONS

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ABSTRACT

It has previously been supposed that as external air temperatures lower following the clustering of the honeybee colony, the cluster temperatures rise. Observations for 2075 hours under controlled temperature conditions show that cluster temperatures remain remarkably constant regardless of external temperatures within certain limits. When there is a significant change in the cluster temperatures, it is in direct relationship with the change in the air temperature, rather than inverse.

Although in general insects are largely dependent upon the temperature of their surrounding medium for their own body temperature, this has not supposedly been the case with the winter cluster of honeybees. The general opinion obtains that after bees form the winter cluster at approximately 57° F., the cluster temperature is raised as the temperature of the air surrounding them lowers. This has been spoken of as an inverse temperature relationship. Among the investigators who have presented data to substantiate this theory are Gates, Phillips, Demuth, Hess and Himmer. Wilson and Milum reported this to be true "up to a variable limit."

In a study of the temperature of the honeybee cluster under outdoor conditions, the writer, after four years experimentation, found that there was not an inversion of temperature relationships. In fact, the mean cluster temperature remained remarkably constant regardless of the range of

outdoor temperatures. The coefficient of correlation between the mean cluster temperature and the mean outside temperature was found to be 0.053 ± 0.026. This correlation is not significant other than that it does not show inversion.

During the course of the above investigations, two series of experiments under controlled temperatures in a cabinet were made. These indicated that continued low temperatures would tend to also pull the cluster temperature down in a more or less direct relationship. It was, therefore, decided to make a more exhaustive study of the temperature relationships of the cluster to controlled external temperatures. The temperature data here presented were gathered in further experimentation upon this matter in conjunction with precision metabolism studies.

TECHNIQUE. The hive used for the experiment was of the 8 frame, full depth, observation type. A portion of the sides could be removed in order to allow the hive temperature to approximate that of the surrounding air.

The controlled temperature compartment in which the bees were placed was that of a Frigidaire ice cream cabinet. This cabinet was cooled by a brine solution, surrounding all sides as well as the bottom. The temperature of the brine was held reasonably constant by means of the thermo-regulator used in conjunction with the expansion coils of the Frigidaire. The cabinet was hermetically sealed and fresh air was supplied through a hose at the rate of 1 cu. ft. an hour.

All temperatures were taken by the thermo-couple method. The equipment used in the determination of temperatures was sensitive to a change of 1/20th of a °F. Forty-two thermo-couples were located between the frames inside the hive. Two were located outside the hive in the air of the compartment. Temperatures were taken every hour, day and night.

The bees used in the experiment were Caucasians. As in all cases but one, these were taken out of winter quarters for the experiment, they were never confined in the cabinet until after a warm period had allowed good winter cleansing flights.

In the analysis of the data, certain groupings of temperatures have been found desirable. Hence, the terminology of the groupings is as follows: "Mean cabinet temperature" refers to the mean temperature shown by the two thermo-couples placed outside the hive and in the air of the cabinet. "Mean hive temperature" is a mean of the five lowest temperatures obtained in the bee-free spaces of the hive. "Mean cluster temperature" is obtained from the five highest temperatures within the cluster. "Mean maximum cluster temperature" is the mean of the one

highest temperature within the cluster. In cases where the means are accompanied by probable errors, they were obtained from a frequency table distribution with the formula $M = A + \frac{\Sigma \xi}{N}$. The standard deviations given were figured from the conventional formula $\sigma = \sqrt{\frac{\Sigma \xi^2}{N} - \delta^2}$.

Results

Series Number 1. The bees in series number one were confined in the cabinet from December 5, 1930 to January 2, 1931. There were 17,517 bees in this colony. The mean cabinet temperature was varied from 15.2° C. to —14.9° C. After 329 hours exposure to this latter low temperature, approximately two-thirds of the bees were still alive.

Table 1. Consolidated Temperature Data for Series Number 1, December 5 1930 to January 2, 1931

Chronological order of periods	Length of period in hours	Mean cabinet temperature in degrees C.	Probable error of the mean ±	Standard Deviation of the mean	Mean Hive temperature in degrees C.	Probable error of of the mean ±
3	42	15.2	0.26	2.58	17.0	0.34
1	117	11.5	0.07	1.25	18.4	0.08
4	65	9.6	0.05	0.70	13.1	0.10
2	116	2.5	0.08	1.32	9.0	0.15
5	329	—14.9	0.04	1.08	—12.3	0.05

Standard deviation of the mean	Mean cluster temperature in degrees C.	Probable error of the mean ±	Standard deviation of the mean	Mean maximum cluster temperature in degrees C.	Probable error of the mean ±	Standard deviation of the mean
3.36	28.7	0.24	2.35	29.7	0.27	2.64
1.33	28.3	0.06	1.08	29.9	0.06	1.00
1.20	26.0	0.16	1.93	27.3	0.12	1.54
2.42	26.0	0.07	1.14	29.0	0.06	1.10
1.36	22.7	0.08	2.21	28.0	0.04	1.11

Table Number 1 gives the essential temperature data for this series. The cabinet temperatures were held reasonably constant, especially at the lower temperatures. The mean cluster temperature gradually lowers as the cabinet temperature is lowered. This is not significant, however, until the temperature of the cabinet is lowered to —14.9° C. It is of importance to note that the highest mean cluster temperaure obtained when the mean cabinet temperature was 15.2° C. It has previously been supposed that at this temperature, the cluster temperature would be lower than at any other temperature range of clustering.

Series Number 2. There were 12,482 bees in this cluster. Only two cabinet temperatures were used and after each had been run, they were checked for shorter periods at the same temperatures.

In both instances, the mean cluster temperature was somewhat lower on the check-in run than on the original. Again the highest mean cluster temperature correlates with the highest mean cabinet temperature. Likewise the lowest mean cluster temperature occurs with the lowest mean cabinet temperature.

The essential data for this series are presented in Table Number 2.

TABLE 2. CONSOLIDATED TEMPERATURE DATA FOR SERIES NUMBER 2, MARCH 6–26, 1931

Chronological order of periods	Length of period in hours	Mean cabinet temperature in degrees C.	Probable error of the mean ±	Standard deviation of the mean	Mean hive temperature in degrees C.	Probable error of the mean ±
1	163	13.8	0.11	1.44	17.5	0.11
3	82	13.3	0.11	1.03	15.4	0.10
2	155	2.8	0.03	0.35	4.3	0.03
4	91	2.8	0.03	0.33	4.2	0.03

Standard deviation of the mean	Mean cluster temperature in degrees C.	Probable error of mean ±	Standard deviation of the the mean	Mean maximum cluster temperature in degrees C	Probable error of the mean ±	Standard deviation of the mean
1.53	31.7	0.04	0.54	33.4	0.02	0.36
0.96	28.3	0.08	0.73	32.6	0.04	0.40
0.40	28.7	0.07	0.93	32.5	0.04	0.51
0.32	24.2	0.15	1.46	28.9	0.14	1.36

SERIES NUMBER 3. This series was made with a constant cabinet temperature. The mean cabinet temperature varied from 5.4° C. to 7.4° C. There were 16,500 bees in the cluster.

TABLE 3. CONSOLIDATED TEMPERATURE DATA FOR SERIES NUMBER 3 BY TWENTY-FOUR HOUR PERIODS APRIL 6–19, 1931

Day in April 1931	Mean cabinet temperature in degrees C.	Mean hive temperature in degrees C.	Mean cluster temperature in degrees C.	Mean maximum cluster temperature in degrees C.
6	7.4	15.5	29.3	30.9
7	6.2	10.6	29.8	31.3
8	6.2	10.0	31.9	32.8
9	6.2	9.2	31.5	32.7
10	6.0	8.3	31.1	32.1
11	5.8	8.2	30.5	31.5
12	5.7	8.0	30.0	30.5
13	5.6	8.0	30.9	32.0
14	5.4	7.8	30.7	31.9
15	5.8	8.1	31.3	32.5
16	5.8	8.4	31.7	32.8
17	5.6	8.3	31.1	32.5
18	5.8	9.0	31.5	32.7
19	5.7	9.0	31.5	32.4

The mean temperatures given in Table Number 3 are arithmetic means figured from an array of 24 observations for each 24 hour period. Al-

though the experiment was conducted for only 14 days, it is surprisingly remarkable how even all the temperatures of the cluster remained.

SERIES NUMBER 4. This colony differed from others in that most of the bees were young, following at least two good cycles of brood rearing. However, brood rearing was not allowed to go on in the cabinet. The bees were placed in a package with the queen caged prior to confinement in the temperature compartment. They were immediately placed in a temperature of 7.5° C. when the queen was released. This stopped further egg laying. There were 11,998 bees in this colony.

The data for this series are given in Table Number 4. The mean cluster temperature remained unusually constant. The greatest variation is from 28.5° C. to 29.3° C. There is no indication of temperature inversion, however.

TABLE 4. CONSOLIDATED TEMPERATURE DATA FOR SERIES NUMBER 4. JUNE 6–31, 1931

Chronological order of periods	Length of period in hours	Mean cabinet temperature in degrees C.	Probable error of the mean ±	Standard deviation of the mean	Mean hive temperature. in degrees C	Probable error of the mean ±
7	48	14.8	0.20	1.07	18.8	0.56
4	72	14.2	0.26	1.85	19.6	0.33
1	120	7.5	0.01	0.12	9.3	0.17
5	48	7.2	0.13	0.92	9.7	0.13
2	120	—0.2	0.03	0.41	0.7	0.07
6	48	0.0	0.16	1.06	0.1	0.06
3	72	—6.5	0.10	0.90	—5.0	0.14
8	48	—6.2	0.18	0.93	—4.1	0.17

Standard deviation of the mean	Mean cluster temperature in degrees C.	Probable error of the mean ±	Standard deviation of the mean	Mean maximum cluster temperature in degrees C.	Probable error of the mean ±	Standard deviation of the mean
3.00	29.3	0.09	0.50	30.0	0.10	0.55
2.33	28.9	0.10	0.73	29.5	0.12	0.83
1.89	29.2	0.08	1.04	29.8	0.06	0.70
0.92	29.3	0.03	0.22	30.3	0.07	0.50
0.83	29.2	0.06	0.73	29.7	0.03	0.42
0.43	28.5	0.09	0.62	29.8	0.10	0.67
1.19	28.6	0.05	0.46	29.2	0.02	0.20
0.89	28.6	0.06	0.33	29.2	0.07	0.38

CORRELATION COEFFICIENTS. All of the data for each hour of the four series were cast into correlation tables and the coefficients of correlation determined. This included 2,075 hourly observations. The coefficient of correlation between the mean cluster temperature and the mean hive temperature is 0.625 ± 0.009. The coefficient of correlation between the maximum cluster temperature and the mean hive temperature is 0.470 ± 0.011.

This is a significant positive correlation. It is considerably more than in the case of that previously cited for outdoor conditions. This is probably due to the pulling down of the cluster temperatures during the 329 hour run at a mean cabinet temperature of — 14.9° C. during Series Number 1. Such a situation would not obtain under natural conditions. For other temperatures in the various series it is apparent that the correlation would be slight, though positive.

CONCLUSIONS. From the data presented it is concluded that:

1. There is no inversion of the cluster temperature in relation to the hive temperature as the temperature of the air surrounding the bees drops below the clustering temperature.

2. Any change in the cluster temperature which takes place is in direct relationship to the change in the air temperature below the clustering temperature.

3. Within rather broad limits, the cluster temperature remains fairly constant regardess of external temperatures. It drops greatly only after long exposure to sub-zero C. temperatures.

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NEW METHODS APPLIED TO STUDIES ON THE SUGAR CONTENT OF NECTARS[1]

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ABSTRACT

Results of recent experiments by the writer show that the honeybee changes the concentraton of nectar or sirup only very slightly while gathering a load and carrying it to the hive. The change is a decrease instead of an increase as has been assumed by many heretofore. The amount of decrease varies directly with the concentration of the nectar or sirup. Observed decreases varied from one-fiftieth of 1 per cent on a 13 per cent sirup to 1.8 per cent on a 64 per cent sirup. The average decrease for Iowa nectars commonly gathered by the honeybee is about 1 per cent. For most practical purposes, it may be considered that the honeybee does not materially change the concentration of nectar while gathering a load of it and carrying it to the hive. Honeysac contents of honeybees captured while gathering nectar from a given plant species, may be used with much confidence for the purpose of obtaining a very close approximation to the actual concentration of the nectar as found in those flowers.

Two great difficulties have stood in the way of securing data on nectar and the factors influencing its production: first the difficulty of obtaining sufficient quantities and, second, the lack of methods of analysis adapted to such small quantities as could be secured. While hand-gathered nectar can be secured in sufficient quantities from a number of species, there are many kinds of nectar bearing plants from which it cannot be gathered satisfactorily by hand. Some of our best honey crop sources, such as the clovers, are among the latter. A real need has existed for the development of methods which would enable investigators to study nectar produced in the small types of flowers also.

An answer to the above mentioned need was discovered, unexpectedly, during the course of an investigation of the methods used by the honeybee in the changing of nectar into honey. In the above mentioned investigation, the writer was faced with these questions: *Does the honeybee change the concentration of nectar while en route to the hive?* If so, is the concentration increased or decreased, and to what extent? Does the change vary in direction or extent with the original concentration of the nectar? In case an increase is shown, is it sufficient to account for an appreciable thickening of the nectar?

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[2]The author wishes to give full credit and grateful acknowledgment to George W. Snedecor, professor of mathematics, Iowa State College, for making a statistical study of the data presented in this paper, and for checking the manuscript with regard to all statements based upon his study.

Widespread opinion, supported by some evidence (1, 2, 3, 4, 5, 10) has held that the honeybee possesses some physiological means for eliminating a portion of the surplus water from nectar while en route to the hive. In the opinion of the writer, however, no such function has ever been conclusively demonstrated. Experiments were begun in 1926 at the Iowa Agricultural Experiment Station, in an attempt to find definite answers to the above questions.

Results of preliminary experiments (7) seemed to indicate that, instead of the supposed increase, there probably was a small decrease in the concentration of nectar while in the honeysac of the field-bee. Definite conclusions were not warranted by the results of these experiments owing to the meagerness of the data and to certain faults in the technique used. Further experiments, using improved technique, were planned on a scale which was considered sufficiently large to yield satisfactory data from which to draw definite conclusions.

Should the indications suggested by the results of the preliminary experiments be fully substantiated by further experiments, it seemed probable that it might be found possible to obtain fairly close approximations to the concentration of floral nectars by means of determinations made upon honeysac contents of bees captured on the flowers while gathering their loads.

EXPERIMENTAL. The general plan of the investigation was to compare the sugar concentration of the honeysac content of the bee entering the hive, with that of nectar or sirup taken directly from the same source from which the bee obtained her load. Three sets of experiments were carried out in consonance with this general plan. A report (7) covering the first two, has been published, and to conserve space, they will not be reviewed here.

Methods which eliminated various defects in procedure had been devised, one after another, during the course of the preliminary work. Short-cuts, such as the use of colored (7) nectar or sirup for purposes of identification, and the Abbé refractometer (8, 9) for making determinations on changes in sugar concentration, had opened the way for conducting the third series of experiments on a much larger scale and with more trustworthy results.

FIELD-BEES CARRYING SIRUP ONE-HALF MILE. Briefly stated, the final series of experiments was conducted on the following plan. Bees of a given colony were trained to go a distance of half a mile (800 meters) to a feeder containing colored sirup. As the color of the sirup was visible through the bee's abdominal wall, those having loads from the feeder were easily recognized, and could be captured as they alighted

at the hive. Captured bees were killed and their honeysacs removed without delay. As each honeysac was removed, its content was deposited

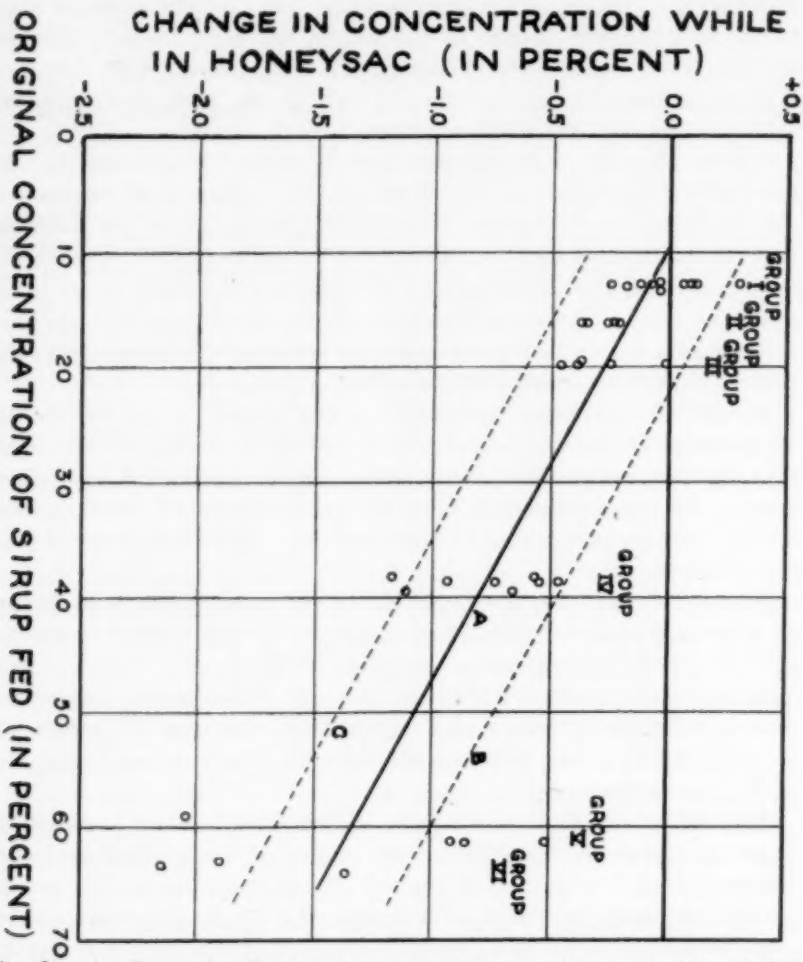

Fig. 51.—A. Regression line based upon mean changes in concentration of sirup while in the honeysac. The standard error of estimate (0.332) is represented by the vertical distances of the two dotted lines, B and C, from A. Mean changes are represented by the small circles.

between the prisms of the refractometer and the refractive index recorded at once. Similar determinations were made at intervals upon samples of sirup taken directly from the feeder. Three determinations for each sample from the feeder were made, as a rule, and the average

taken. Changes in concentration could then be found by comparing these two sets of data.

Six different concentrations of sirup, varying from 13 to 65 per cent, were used. Changes made by the bees in the concentration of the sirups of various initial concentrations, were found and tabulated,[3] after which the data were subjected to statistical treatment, using R. A. Fisher's method of analysis of variance (6). This test showed the results to be homogeneous within each of the six concentration groups, but that significant differences exist between the groups.

A regression line, based upon the changes found, has been plotted and appears in Fig. 51. The equation used in the derivation of this line is as follows:

Estimated change = .2525 — .02665 (feeder concentration).

The line may be looked upon as representing the average change in groups of approximately 10 bees, for sirups of concentrations between 13 and 70 per cent. This estimated average change is found to have a standard error of 0.332 which is represented in Fig 51 by the space bounded by the two dotted lines, one of which lies on either side of, and parallel to, the regression line. In normally distributed data, about 68 per cent of the group means would fall within the area between these dotted lines. Upon plotting the data, it was found that 75 per cent of the means fell within this area.

As may be observed from Fig. 51, a few slight increases in concentration occurred when the 13 per cent sirup (group I) was used, but all other mean changes were decreases. The amount of decrease was found to vary directly as the original concentration of the sirup. The maximum average change to be expected in a 65 per cent[4] sugar solution was found to be approximately 1½ per cent. It is concluded, therefore, that sugar determinations made on the honeysac content of bees gathering from a given source, differ from determinations made on the original supply, by small percentages only.

The constancy of the honeybee to her chosen floral species is too well established to require more than mere mention. Likewise, it is well known that nectar contains little else than sugar and water. Hence we may conclude that sugar determinations on the honeysac content of a bee

[3]Data in full are given in a more extensive presentation of this investigation which will appear, forthwith, as Bulletin 151 of the Research Series from the Iowa Agricultural Experiment Station.

[4]Extensive investigations by the writer, mostly unpublished, have shown that the concentration of nectar in most Iowa honey plants usually varies between 30 and 65 per cent during that part of the day in which they are gathered by the honeybee.

caught while gathering from a given kind of plant, must give a close approximation of the sugar content of the nectar as it existed in the flowers visited by this bee.

Even the small error which would be present in results obtained by means of determinations on honeysac contents, may be considerably reduced through the use of the following regression equation:

$$\text{Estimated nectar concentration} = 1.0271\ (\text{Honeysac concentration}) - .2513$$

This equation is based upon the same original data as were used to obtain the former regression. In this case, however, we start with the concentration of the honeysac contents and work back to find the concentration of the original sugar solution. A series of values has been

TABLE 1. VALUES FOR THE CONCENTRATION OF SIRUP AT THE FEEDER, OR NECTAR IN THE FLOWERS, AS ESTIMATED FROM THE CONCENTRATION OF HONEYSAC CONTENT*

Concentration of honeysac content	Estimated nectar or sirup concentration
Per cent	*Per cent*
10	10.02
15	15.16
20	20.29
25	25.43
30	30.56
35	35.70
40	40.83
45	45.97
50	51.10
55	56.24
60	61.37
65	66.51
70	71.65

*On a basis of 10 honeysacs determined individually.

listed in Table 1, showing the estimated concentration of the original sugar solution, as found from the above equation, when the concentration of honeysac contents, obtained by the bees from the same source, has been found from 10 or more honeysacs individually determined.

Studies were made also upon certain factors which were considered to have a possible bearing upon the change in concentration of nectar while in the honeysac of the field-bee. The following factors were studied: 1. Influence of duration of retention of sirup or nectar in the honeysac. 2. Influence of "carry-over" from previous load. 3. Influence of flight.

Only the conclusion derived from these studies can be presented here because of limited space. The general conclusion is that if the observed change in concentration is influenced by any of the factors listed above,

such influence is so slight as to be relatively unimportant and may be disregarded when using an average based upon determinations from 10 or more honeysacs.

ADVANTAGES OF NEW METHOD. Certain advantages arise from the use of honeysac contents in the determination of the concentration of sugar in the nectar produced by various plants. Nectar samples may be obtained by this method from small types of flowers such as sweet clover, *Melilotus*, from which it is practically impossible to collect nectar by hand. Samples may be secured more rapidly from bees than from flowers directly, in most instances. Many chances of making mistakes of one kind or another are eliminated when the bee does the gathering, for she will not take water in lieu of nectar, while man might easily do so. There is less liklihood of errors due to evaporation in collecting and handling the nectar, than in the case of collections made by hand, especially when dealing with very small flowers or those which yield nectar in very small quantities. On the whole, samples collected by bees probably are more truly representative than are those collected by hand.

ENLARGED POSSIBILITIES FOR THE STUDY OF NECTARS. The present investigation has shown that only an insignificant change occurs in the concentration of a sugar solution while in the honeysac of the bee. It has been found also that the Abbé refractometer method is practical, and, for general purposes, sufficiently accurate for determining the sugar concentration of nectar. The Abbé refractometer method requires only minute quantities of nectar, and such quantities as are needed may be secured readily from the sacs of honeybees captured while gathering nectar from the species of flowers to be investigated. Thus, both of the difficulties mentioned in the introduction have been practically eliminated, and it will now be practicable to study nectar concentrations in a large number of species of flowers which could not have been investigated through the use of the older technique.

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EFFECT OF COLD STORAGE TEMPERATURES ON THE ARGENTINE ANT

By FRANK B. HERBERT, *Entomologist, Balfour, Guthrie & Co., Limited, San Francisco, Calif.*

ABSTRACT

A record of mortality of the Argentine Ant at various temperatures and periods of time.

Information was requested as to what temperature was necessary to kill Argentine ants, which had gotten into a cold room from some oranges being stored. I was informed that it would be possible to hold this room at 10° Fahrenheit for three days and the informer wished to know if this would kill them. My reply and that of those I asked was that it probably would.

As there seemed to be no reference to this in the available literature, the writer determined to obtain a positive answer by experimentation.

After capturing several thousand of these ants in jars baited with raw meat, which were then covered with muslin, they were placed in rooms of constant temperatures ranging from 5° to 31° Fahrenheit.

Although other species of ants are said to withstand low temperatures effectively, it is interesting to note that all the Argentine ants died in 24 hours or less in these temperatures. This is probably the reason this tropical species has not advanced farther into the colder countries.

The following table indicates their mortality at various temperatures.

TABLE OF ARGENTINE ANT MORTALITY

Date 1931	No. of ants incarcerated	Relative humidity	Temperature ° Fahrenheit	Per cent mortality after 1 Hr.	2 Hrs.	4 Hrs.	24 Hrs.
Aug. 27	600	55	6–7°	—	—	—	100
Aug. 27	600	60	10–12°	—	—	—	100
Aug. 27	600	65	15–16°	—	—	—	100
Aug. 27	300	80–85	31–32°	—	—	—	100
Aug. 31	500	55	3½°	52	100	—	—
Aug. 31	500	60	5–6°	63	100	—	—
Aug. 31	500	65	11–12°	22	31	100	—

Temperatures somewhat higher than 31° were not available so that the maximum cold temperature necessary for mortality was not determined, although it is probable any above freezing would no more than cause them to cease activity during this incarceration.

Within two hours after removing the ants to warm temperatures, most of those from the 31° room showed signs of life, but they all finally died within 24 hours. This was not due to a lack of food or water. Ants in the check, 60° to 80° Fahrenheit, survived until the discontinuance of the experiment a week later.

SUMMARY. Argentine ants will succumb in 24 hours if held at a temperature of 31°, or in a shorter time if held at lower temperatures.

NOTES ON THE SYNONOMY, HOSTS AND DISTRIBUTION OF SOME *BUPRESTIDAE* (COLEOPTERA)[1]

By W. J. CHAMBERLIN, PH.D., *Forest Entomologist, Oregon State College*

During the past several years there has been accumulated numerous notes on the distribution of several species of Buprestidae which probably should be made available. Those records which extend the distribution of a species into a state not previously reported are given below, together with other notes which may be of interest.

Dicerca pecterosa Lec. has not previously been reported from Washington. A specimen was collected by Mr. Shirck at Toppenish, Wash., April 25.

Dicerca lurida Fab.—Although previously reported from Oregon,[2] it is interesting to note that an additional specimen was taken in 1929 and one in 1930.

Dicerca divaricata Say.—This eastern species has not been noted previously as occurring in Oregon. On May 6 a typical specimen was taken at Corvallis.

Buprestis gibbsi Lec.—Specimens of this rare species are taken but seldom and usually accidentally. During the past summer (July and August) four speciments (1 ♂ and 3 ♀) were taken in pea weevil traps placed near oak woods in the vicinity of Corvallis by Mr. A. O. Larson of the Bureau of Entomology.

Buprestis aurulenta Linn.—During the past 15 years we have ex-

[1]Published as technical paper No. 171 with the approval of the Director of the Oregon Agricultural Experiment Station. A contribution from the Department of Entomology.

[2]1924—Chamberlin. Journ. N. Y. Ent. Soc. XXXII, p. 185.

amined many hundred adult specimens of Buprestidae without noting any evidence of parasitism. On July 17 a specimen of *B. aurulenta* was taken with two eggs of a tachinid fly firmly attached to the dorsal surface (Fig 52). The specimen was kept in a cage but died on the fifth day. The eggs hatched, but whether the maggots made their way through the exoskeleton or not has not been ascertained. The egg appears to be that of a common parasite of the tent caterpillar, which was abundant during the past summer.

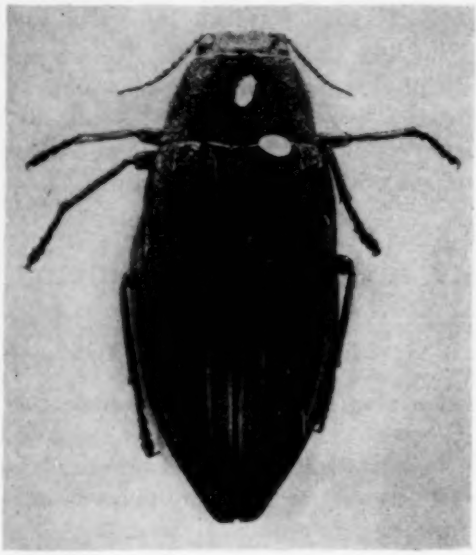

FIG. 52.—*Buprestis aurulenta* Linn. with eggs of a tachinid fly attached.

Buprestis adjecta Lec. was reported as probably breeding in lodgepole pine (Journ. N. Y. Ent. Soc. Vol. 33, p. 188 and Ent. News XXVIII, p. 133) as specimens had been taken on that tree. In August 1930 two specimens were taken from their galleries in weather beaten *Pinus contorta* at Miller Lake, Deschutes National Forest, Oregon.

Chrysobothris laracis Van Dyke.—This species has for the first time been taken west of the Cascade Mountains in Oregon at Oak Ridge in May.

Chrysobothris nixa Horn has not previously been reported north of Oregon, so that the following record extends the distribution several hundred miles and adds the name of an unpublished host plant. Mr. C. A. Hardy, formerly of the Provincial Museum at Victoria, dug a number of specimens from *Thuja plicata* at Millstream, Vancouver Island, B. C.

Chrysobothris monticola Fall.—In a box of material recently submitted for determination were two males and one female of this species taken from *Pinus contorta* at Copper Mountain, B. C., by Stacey Smith. Both the host and locality are new for this fine species.

Chrysobothris dolota Horn.—A specimen has been seen, taken on Mt.

Adams, Washington, August 2. The species has not been recorded previously from that state.

Chrysbothris beyeri Sch.—I do not believe that this species has been reported as having been taken in the United States. There is a specimen labelled La Paucta, San Diego county, California, VIII, 7.27, in the collection of Mr. Fields at San Diego.

Chrysobothris fragariae Fisher.—This species recently described[3] from Washington and Idaho occurs in Oregon and California. In 1926 the writer took specimens of typical Chrysobothris larvae from the roots of *Geum* in Klamath county, Oregon, and Modoc county, California. Unfortunately these were taken at the beginning of a trip to Arizona and did not survive to be reared, but they were undoubtedly larvae of this species. The species also occurs in cultivated strawberries at Roseburg, Oregon.

Acmaeodera variegata Lec.—There is a specimen of this species in the U. S. National Museum labeled Hood River, Oregon. This was taken many years ago by Hubbard and Schwarz. Fall, in his synopsis,[4] states that *variegata* extends its range into Oregon. This statement may have been based upon the specimen mentioned above. It is interesting to record that 3 specimens were taken at Mosier and two at The Dalles, Oregon, and Mr. M. C. Lane has submitted specimens from Vernon, B. C., June 10; from Wawawai, Washington, May 20, and Asotin, Washington, April 15. These records materially increase the geographical distribution of the species. The host plant is still unknown.

Notice has already been published[5] regarding the taking of *Acmaeodera bishopiana* Fall at Adrian, Oregon, showing that typical desert and great basin species migrate northward through our great central plateau regions, some going as far north as British Columbia, as pointed out by Ralph Hopping.

Acmaeodera gemina Horn.—Previously a single specimen of this species was reported from Oregon.[6] On August 15, 1930, H. A. Scullen took a small series in Crater Lake National Park at an elevation of 6000 feet.

Anthaxia deleta Lec. has been reported[7] from British Columbia, Idaho, Oregon and some states to the south. Recently a specimen was secured on Mt. Adams, Washington, at an elevation of 3000 feet.

[3]1930—Fisher, Proc. Ent. Soc. Wash., Vol. XXXII, p. 149.
[4]1899—Fall, Journ. N. Y. Ent. Soc., Vol. VII, pp. 1–37.
[5]1929—Chamberlin, Pan. Pacific Entomologist, Vol. V, p. 111.
[6]1924—Chamberlin, Journ. N. Y. Ent. Soc., Vol. XXXII, p. 187.
[7]1926—Chamberlin, Catalogue of Buprestidae, p. 90.

Agrilus pubifrons Fisher.—This species was described[8] from two specimens, the type from Pocatello, Idaho, and another specimen from Chad's Ranch, Utah, so it is not surprising to find the species in Oregon. Prof. Scullen took a specimen near Prineville, August 12, 1930.

Agrilaxia flavimana var. *arizonae* Chamberlin.[9]—Described in the Catalogue of Buprestidae, is the same as *Agrilaxia arizonae* Obenberger, described in Ent. Blatter XVIII (1922) p. 180. This description was unknown to me at the time (1926) I described the variety.

Agrilus manzanitae Chamberlin is synonymous with *A. arbuti* Fisher; *Agrilus trichocarpae* Chamb., is synonymous with *A. populi* Fisher. These descriptions appeared before Bulletin 145 of the National Museum, containing Fisher's descriptions, was distributed, but I believe Fisher's names have priority. Both species occur in Oregon.

pH AND WIREWORM INCIDENCE[1]

By G. Allen Mail

Abstract

The effect of soil acidity or alkalinity on the abundance of wireworms in Montana is studied. Laboratory experiments show that the larvae of *Limonius canus* can tolerate a much wider range of pH than is commonly found in nature in the agricultural lands of Montana. This is substantiated by field records. The range in pH to which the wireworms were subjected in the laboratory was 4.8 to 8.2. In nature the pH limits in fields studied was 6.1 to 7.7.

Whether high soil acidity or alkalinity has any influence on the abundance of wireworms is not known definitely. The literature on the subject of pH and its relation to living organisms is wide and in many instances controversial. Many studies have been made on the influence of soil reaction on plant distribution by Wherry (6), Salisbury (5) and others. The soils best adapted to crop production have been studied with respect to their pH reaction by Kelly (4) and Gillespie and Hurst (3). The literature on the influence of soil acidity on animals living in the soil is less abundant and much work yet remains to be done on this problem. Plants are more or less static and an unfavorable condition

[8]1928—Fisher, U. S. National Museum Bul. No. 145, p. 239.

[9]1929—Chamberlin, Pan. Pacific Entomologist, Vol. V, pp. 112-113.

[1]This work is part of a cooperative project between the Montana Experiment Station and the Bureau of Entomology, U. S. D. A.

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of soil acidity will result in the elimination of susceptible plants. Arthropods can go down to escape unfavorable conditions. The close relation that exists between arthropods, such as wireworms, and their plant hosts may, however, make crop production studies in this regard significant.

Allee, Torvik, et al (2) have made studies on the influence of soil reaction on earthworms in Illinois and Indiana. In these studies they found that the six species of earthworms studied tolerated a wide range of pH, from 5.8 to 8.3. Arrhenius (1), on the other hand, found that earthworms are very strongly influenced by the reaction of the soil, so that they can live only in slightly acid or neutral soils, and that the presence or absence of earthworms in the soils is dependent on its reaction.

Many of our economic species of Elaterids are wholly subterranean during their larval and pupal life and as this period may last as long as five years, it is important to know just what is the influence of the hydrogen ion concentration of the soil on these larvae.

TECHNIQUE. In these studies the wireworms were reared under controlled conditions in sand of known pH, a white silica sand being used. In order to insure that the sand was quite inert and that there would be no chemical interaction between it and the buffer solutions used, it was treated as follows: It was first washed in 10% Sodium Hydroxide for a few days to dissolve out any alkali soluble materials, then washed with distilled water, and washed in 10% Hydrochloric Acid to take care of any acid soluble materials present. After final washing in distilled water, drying and sifting it was ready for use. The buffer solutions used were Sodium Hypophosphate ($Na_2HPO_4.12H_2O$) and Potassium Acid Phosphate (KH_2PO_4). Battery jars were filled with buffered sand, the pH of the sand in the different jars being as follows:

1	4.8	5	7.3
2	5.9	6	7.9
3	6.4	7	8.2
4	6.9		

Check—Distilled water only.

Larvae of *Limonius canus*,[2] less than one year old, being three to six millimeters long, were used. They were placed five in each salve box of treated sand with sprouted wheat for food. There were prepared ten of such boxes for each sand of known acidity. The boxes were examined once a week and the sand changed for fresh material from the appropriate stock jar, fresh wheat being added at the time. The boxes were kept at a constant temperature of 22° C.

[2]This wireworm, in Montana at least, is found only in the irrigated sections, where, however, it does considerable damage.

RESULTS

The survival table below shows the mortality after two months in the environment indicated.

TABLE 1

Lot No.	pH	Survival out of 50 wireworms
1	4.8	92%
2	5.9	44
3	6.4	56
4	6.9	54
5	7.3	32
6	7.9	42
7	Distilled water	34
8	8.2	60

Mortality was high in each lot, even the neutral sand moistened with distilled water having only 34% survival after two months. Most of this high mortality was due to cannibalism, chiefly of larvae which had recently molted. Some mortality was also attributable to the excessive drying out of the sand and consequent desiccation of the larvae in boxes affected. The fact remains that a high percentage of larvae survived in a healthy condition in extremely acid and extremely alkaline environments. It would thus appear that soil reaction has little if any effect on wireworms, at least in the Northwestern portion of the United States.

In order to correlate these laboratory data with conditions in nature, many soil samples were taken in the field and tested for their pH value. These samples were taken at depths of 3, 6, 9, and 12 inches, and placed in salve tins which were sealed with adhesive tape. Samples were taken from fields which had never been known to be infested, fields that had had a history of previous infestation and fields heavily infested at the time of sampling. The pH of the soil samples was ascertained by centrifuging for 5 minutes and testing the supernatant liquid with a set of LaMotte standards. Gillespie and Hurst (3) found that the results by electrometric and simple colorimetric methods were approximately correct within the ranges of pH 4.4 to 8.6.

The data obtained are shown in Table 2.

It will be noticed that the soils tested do not show a very wide range of pH and worms were found in soil only as acid as pH 6.1 and as alkaline as pH 7.7. In some cases worms have been present and doing damage for several years, e.g. the field from which sample No. 32 was taken. In 1926 this field was seeded to oats which were almost completely destroyed by wireworms which also took two-thirds of the reseeded crop. In 1927 wheat was severely attacked. In 1928 the field was summer fallowed and in 1929 the worms worked on wheat. In 1930 this field was seeded to oats and sweet clover—with little worm damage, the

TABLE 2. FIELD RECORDS OF SOIL TYPE, CROP, AND HISTORY OF WIREWORM DAMAGE

Sample No.	County	pH at depth of 3″	6″	9″	12″	Soil type	Condition of soil	Crop	Previous history	Present* infestation
1	Gallatin	6.5	6.6	6.9	7.1	Clay loam	Moist	W. wheat	None	Heavy
2	Gallatin	6.5	6.3	6.6	6.3	Clay loam	Dry	W. wheat	None	None
3	Gallatin	6.1	6.3	6.5	6.6	Sandy loam	Moist	Wheat	1929	Medium heavy
4	Gallatin	6.6	6.6	6.7	6.8	Dark clay loam	Fairly dry	Wheat	None	Medium heavy
5	Gallatin	6.4	6.7	6.7	6.8	Dark clay loam	Very dry	Wheat	None	Medium heavy
6	Gallatin	6.9	6.7	6.7	6.7	Light sandy loam	Moist	Peas	None	Heavy
7	Missoula	6.7	6.7	6.5	6.5	Light sandy loam	Moist	Corn	1929	Heavy
8	Missoula	6.7	6.7	6.7	7.1	Light sandy loam	Moist	Beets	1928	Heavy
9	Missoula	6.8	6.7	6.7	6.7	Dark clay loam	Fairly moist	Garden crops	None	None
10	Missoula	6.5	6.5	6.6	6.6	Dark clay loam	Fairly moist	Beets	1929	None
11	Missoula	7.1	7.3	7.3	7.3	Sandy loam	Moist	Ornamental flowers	None	None
12	Missoula	6.7	6.9	7.3	7.1	Light sandy loam	Moist	Truck garden	4 years	Very heavy
13	Missoula	7.1	7.0	6.9	6.8	Light sandy loam	Moist	Truck garden	1929	Heavy
14	Missoula	6.9	7.1	7.2	7.3	Light sandy loam	Wet	Cabbage	1929	Very heavy
15	Missoula	6.5	6.5	6.9	7.4	Light sandy loam	Moist	Corn	None	Heavy
16	Sanders	6.9	6.6	—	—	Light sandy loam	Moist	Garden	Many years	Medium heavy
17	Sanders	6.5	6.5	6.5	6.5	Light clay	Dry	Potatoes	None	None
18	Sanders	7.1	6.6	6.6	6.5	Light clay	Dry	Corn	None	None
19	Stillwater	6.5	6.5	6.5	6.9	Stony lt. sandy l.	Dry	Wheat	1929	Light
20	Stillwater	6.5	6.6	6.6	6.7	Stony lt. sandy l.	Moist	Wheat, barley	1929	Light
21	Stillwater	7.1	7.1	7.3	7.6	Stony lt. sandy l.	Dry	Wheat	None	None
22	Stillwater	7.5	7.5	7.4	7.3	Stony lt. sandy l.	Moist	Wheat	None	None
23	Fremont Co. (Ida.)	6.4	6.5	6.5	6.6	Dark loam	Moist	Peas—lettuce	1929	Heavy
24	Flathead	6.5	6.4	6.7	6.8	Dark loam	Moist	S. fallow	None	None
25	Hill	6.5	6.5	6.5	6.6	Light sandy loam	Dry	S. fallow	Every year	Light
26	Hill	6.5	6.6	—	—	Light sandy loam	Dry	Wheat	None	None
27	Blaine	6.8	7.0	7.1	7.7	Light sandy loam	Dry	Wheat	None	None
28	Blaine	6.8	7.0	7.1	7.7	Light sandy loam	Dry	Wheat	1929	Medium heavy
29	Blaine	6.9	7.3	8.1	8.1	Sandy loam	Dry	Wheat	None	None
30	Gallatin	6.5	6.7	6.7	6.8	Dark loam	Dry	Wheat	None	None
31	Gallatin	6.4	6.5	6.5	6.6	Dark loam	Wet	S. fallow	None	None
32	Phillips	6.5	6.3	6.5	6.5	Sandy loam	Dry	Wheat	1926	Light
33	Phillips	6.7	6.8	6.7	7.3	Sandy loam	Dry	Oats	1926	None
34	Gallatin	7.0	7.1	7.1	7.3	Light sandy loam	Dry	Wheat	1928	None

*The species involved are *Ludius inflatus*, *Ludius aeripennis*, *Limonius canus*, and a few less important species.

sweet clover suffering most. In this particular field the injury was apparent only in the low places, the knolls never having shown evidence of wireworms. These low places were slightly acid, testing pH 6.3 at 4 inches and pH 6.5 at 12 inches. The knolls tested pH 6.8 at 4 inches and pH 7.3 at 12 inches. This has no significance in view of the laboratory and other field data as it is clearly demonstrated that worms will easily survive and develop normally under much more acid and alkaline conditions.

Conclusion

The particular wireworm (*Limonius canus*) used in this experiment is able to tolerate a wide range in soil acidity, a much wider range than is customarily found in nature, in Montana at least. It is therefore concluded that the pH value of the soils in Montana which are suitable for and are used to grow agricultural products, has no influence on the presence of wireworms, and that other factors must be considered in seeking an answer to this problem.

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THE STRAWBERRY ROOT-WEEVIL, *BRACHYRHINUS (OTIORHYNCHUS) OVATUS* AS A CONIFER PEST[1]

By E. I. McDaniel, *Michigan State College*

Abstract

Apparently there has developed a distinct race of the strawberry root-weevil, *Brachyrhinus ovatus*, the larvae of which feed only on the root systems of two- and three-year-old conifer seedlings growing in seed beds. The infestation has built up among growing conifers for a quarter of a century or more in a comparatively restricted area. The larvae in the soil can be killed by the use of carbon disulphide emulsion used at the same strength recommended for the control of the Japanese beetle. The adults can be killed by the use of poisoned bran bait, made according to the same formula recommended for the control of cutworms, except that oil of apples in place of amyl acetate should be used as an attractant. When the three-year-old seedlings are removed from the seed-beds in the early spring and transplanted to clean soil, the loss will be reduced.

Early in the spring of 1929 a severe infestation of *Brachyrhinus (Otiorhynchus) ovatus* was discovered in a small conifer nursery in central Michigan. All three-year-old conifer seed beds were infested and some evidence of injury showed up in the two-year-old beds.

During the three years that the infestation has been under observation, the damage caused by this insect has steadily increased. In 1929 it was necessary to discard one-third of the conifer seedlings from the three-year-old beds; in 1930 at least two-thirds of the three-year-old seedlings were killed; and in 1931 all three-year-old plantings of Norway spruce, white spruce, white pine, red pine, western yellow pine, and white cedar were a total loss.

Possibly the weevil working in this nursery is a special strain of the strawberry weevil, for while there are many strawberry plantations in the vicinity, no injury from this weevil has been detected there in either cultivated or wild berries and when caged with strawberry plants, both in the open and in the laboratory, larvae and adults starved, while those caged on conifers developed normally.

The particular plot of sandy soil on which the trees were grown has been used for a conifer nursery for at least 25 years. It has been the practice to fertilize well and to leave the ground fallow every fourth year, the new beds of necessity being in close proximity to the fallow ground.

The conifer destroying strain of the strawberry weevil, in common with its relatives, shows a decided preference for young plants grown in compact seed beds. New beds on clean soil were not infested at the

[1]Authorized as Journal Article No. 88 (N.S.) from the Mich. Agr. Exp. Sta.

end of the first year, but at the end of the second year the top growth was sufficient to furnish shelter, and by that time a root system capable of sustaining the larvae had developed. When the seedlings were three years old and ready to transplant, it was possible to take 500 or more larvae from a sample of soil one foot square and six inches deep.

Where seed-beds are examined in April or May, most of the larvae will be found within six inches of the surface. However, it is not unusual to find them down from eighteen to twenty-two inches deep, and occasionally in working over an empty seed-bed they have been found collected in pockets two feet below the surface. All appreciable damage is done in the larval stage, some feeding takes place in the summer and early fall before the larvae go down deep in the soil, though most of the injury is inflicted by the mature larvae in the spring before pupation takes place.

The larvae attack the seedlings from the ground level down 5 or 6 inches, gnawing the bark from the main stem and root branches. Many seedlings, in an attempt to overcome this underground girdling, develop secondary root systems at the ground level or even above the surface.

Early in the spring it is difficult to select infested seedlings from a superficial study of the top growth. True, the young trees appear stunted, but usually the color remains normal until late in the spring. Repeated experiments have proved that where the bark on the tap-root is injured to any appreciable extent the young tree will not live. Very little injury is suffered by young transplants, even when set out in ground from which three-year-old seedlings have been recently taken—ground which is literally teeming with larvae. Where any noticeable injury occurs at all, it is confined to the lateral root systems rather than to the tap-root.

In 1929 adult overwintering beetles were found as early as April 25th. Overwintering larvae started to pupate about May 10th. The first adults from the overwintering larvae appeared June 3rd. By June 30th practically all adults had emerged. The observations on life-history for 1930 and 1931 have confirmed those made in 1929.

When the three-year-old seedlings are removed from the seed-beds, all soil should be carefully shaken from their roots to dispose of any weevils, and the roots should be puddled or heeled in. After removing the seedlings, of course, myriads of larvae are left in the empty seed-beds, and if no precautions are taken, the larvae will complete their development feeding on the fine roots left in the soil, and emerge as adults to reinfest other seed-beds.

Preliminary experiments with arsenate of lead used at the rate of 5

pounds to 1000 square feet, and white arsenic used at the rate of 80 pounds to the acre, gave promising results. The plots were treated in April shortly after a bed of three-year-old white cedars had been removed from the soil. Cages measuring 8 feet long by 4 feet wide covered with wire screen were placed over portions of the treated area and, when examined about the last of June, 183 adult beetles and 92 pupa were taken from the plot treated with arsenate of lead, 10 adults and 66 pupae were taken from the plot treated with white arsenic, while 490 adults and 13 pupae were recovered from the check.

A number of experiments have been carried out with attractants, repellents, soil disinfectants, and poison baits. Several of these gave sufficient promise to be worthy of further investigation. However, at the present moment the three following methods seem the most promising:

Remove the three-year-old seedlings from the seed-beds before the larvae become active in the spring, and "heel in" on soil free from larvae until time to transplant.

Treat soil in infested seed-beds after the seedlings have been removed with carbon disulphide emulsion, using the same strength recommended for the control of the Japanese beetle. Where an emulsion containing 50 per cent carbon disulphide is used, the following dilutions, depending on the temperature of the soil, have been effective:

40° to 50° F.....68 cc. emulsion to 10 gals. of water
50° to 60° F.....57 cc. emulsion to 10 gals. of water
60° to 70° F.....45 cc. emulsion to 10 gals. of water

Pour the carbon disulphide emulsion into the water and agitate. Use 2½ gallons of the diluted emulsion to a square foot. Do not disturb the soil for 48 hours after the treatment.

The adult beetles are attracted to ordinary bran bait, such as is used against cutworms. In our experiments we substituted oil of apples for amyl acetate. The bait was spread late in the afternoon. Three applications were made a week apart, the first application being made when the beetles began to appear in numbers.

OBSERVATIONS ON THE SUGARCANE BEETLE IN LOUISIANA

By J. W. INGRAM and E. K. BYNUM,[1] *Bureau of Entomology, U. S. Department of Agriculture*

ABSTRACT

Sugarcane is injured by the gnawing of the adult (*Euetheola rugiceps* Lec.) into the underground stem of the young plant. Observations show that the number of sugarcane beetles in different places around a plantation varied from zero in woodlands to more than 100,000 per acre in pasture. Owing to the much greater number of early cane shoots produced by planting sugarcane in the summer rather than in the fall, the former practice affords a much better chance than the latter of producing a crop in the areas where the beetle is a serious problem.

The sugarcane beetle (*Euetheola rugiceps* Lec.) was reported as injuring sugarcane in Louisiana as long ago as 1856. Dr. L. O. Howard[2] investigated an outbreak in Louisiana in 1880. There are many records of injury since that time. This species is present throughout Louisiana, but it is only in certain sections that its injurious work is of much economic importance. In addition to sugarcane, the beetle causes serious injury to rice and corn.

SEASONAL HISTORY. The adult is shiny black when newly emerged, but as it ages it takes on more of a dull, worn appearance. It is from 13 to 16 mm. in length and about 7 mm. in breadth. The species hibernates as an adult in the ground. It comes out from hibernation in April and May and begins to feed upon its host plants. Feeding to an injurious extent usually continues during April, May, and the first part of June. The beetle is active above ground mainly at night, although it has been observed on the surface in the daytime.

Oviposition begins in April. The period of heaviest oviposition appears to be during late May and early June, but eggs have been deposited as late as August 14. Most of the overwintered beetles die during the following June and July, but some live until late summer. Eggs are deposited near the host plant beneath the surface of the soil. They are globular in shape and pearly white in color when first laid. Incubation requires about two weeks.

[1]The authors wish to express their appreciation to T. E. Holloway, in charge of sugarcane insect investigations, Division of Cereal and Forage Insects, U. S. Bureau of Entomology for aid and suggestions in carrying on this work. Thanks are also tendered to the Oaklawn Plantation division of the South Coast Company for valued cooperation.

[2]Rept. Comm. Agr. for 1880, p. 236–240. Also Special Report No. 35, U. S. Dept. Agr., 1881.

The larvae feed upon various rotting materials, such as cane trash, grass roots, and cane plants killed by the adults. Some larvae soon become full fed and pupate, but in most cases pupation is more or less delayed. Adults emerge from the early pupae in July and from very late pupae in September, but most individuals reach the adult stage in August. The freshly emerged, shining black adults of the new generation can easily be differentiated from the dull worn individuals that have hibernated. These newly emerged beetles have been found feeding upon old cane plants and upon summer plant cane. The injury at this time appears to be of little economic importance. Beetles were last found feeding in the field on October 17.

TYPE AND EXTENT OF INJURY. Beetle injury to sugarcane takes the form of ragged holes gnawed into the shoots just below the surface of the ground. These holes usually kill the shoot, but a sucker may sprout from below the injured portion. Sometimes the cane shoots are gnawed before they reach the surface of the ground. Heavily injured sugarcane fields are very noticeable because of the characteristic appearance of the injured shoots, the inner leaves of which die and turn yellow.

Counts of dead shoots have been made throughout the sugarcane section. In some instances as high as 70 per cent injury has been found. An average heavily injured field had 4,043 dead shoots and 7,728 uninjured shoots on April 30. No field has yet been observed where all the shoots were killed on any one date, but there is evidence that all the original shoots in a field may be killed at some time during the season. Suckers sometimes grow from the plants that are apparently dead. However, of 95 injured and apparently dead shoots marked in 1931, 37 did not produce any suckers, and 2 others produced suckers less than 3 feet in height at harvest time. Of 552 shoots that were examined, the average number of suckers coming from one original shoot apparently killed by the beetle was 0.58, as against 4.65 suckers from one uninjured plant. The average stalk growth at harvest time, counting only stalks 3 feet high and over, was 11.50 feet per injured stool, and 44.70 feet per uninjured stool. Average stalks, cut from each set of marked stools, showed the uninjured stalks to be 23 per cent heavier and yielding 5.74 pounds more sugar per ton of cane than the injured stalks. The aforementioned experiment was conducted in a field of P. O. J. 234 plant cane located about midway between Bayou Teche and Grand Lake on a plantation near Franklin.

One plantation manager near Franklin estimated his loss on 2,142 acres of sugarcane at 4,801 tons, or about 2¼ tons per acre. Fortunately, heavy beetle injury is restricted to the general section around Franklin,

with scattered small infestations elsewhere in the State. The Franklin section is reported to suffer some loss from the beetle practically every year, although the injury during 1931 was probably heavier than usual. In other sections the beetle problem is mainly one of occasional outbreaks.

Losses from beetle injury are usually greater in plant than in stubble cane. One reason for this is the differing number of original shoots per acre. In the section around Franklin, in early May, plant cane had an average of 8,500 shoots per acre; while first-year stubble had an average of 13,944 shoots. Stubble also appears to have greater ability to put out suckers from injured shoots. The soil around plant cane permits the beetle to reach the shoots and move from one shoot to another with greater ease.

ENVIRONMENT PREFERENCES. In an attempt to locate the breeding grounds of the beetle, soil was examined in different areas on a plantation near Franklin during the time between the occurrence of oviposition and the emergence of the new beetles. Thirty square feet of soil were examined in various areas to a depth of 8 inches. Beetle stages were found in the following numbers:

	Number of beetles per acre
Woodlands, in front and rear of plantation	0
Corn and soybeans	279
Plant cane	479
Stubble cane, near Bayou Teche	2,768
Stubble cane, midway between bayou and lake	2,964
Stubble cane, near Grand Lake	4,671
Bermuda sod between levee and Grand Lake	50,820
Mixed grass sod between levee and Grand Lake	14,520
Carpet and Bermuda sod alongside plantation road	29,040
Mainly broom sedge alongside plantation road	7,260
Carpet and Bermuda pasture, 12 to 18 feet from bayou	101,640
Same area, 18 feet to one-fourth mile from bayou	49,005

The results of these findings as to environment preference were further verified from breeding cages located in the different areas and by larval food experiments in cane in the insectary. It will be seen that plant cane and first-year stubble cane must certainly be infested by beetles breeding outside of these fields. Second-year stubble cane is evidently infested from the outside to a less extent. Using the preceding figures, and estimating one beetle to kill two original shoots, it will be seen that the beetles from one acre of bayou sod land would be capable of attacking all original shoots in 23.9 acres of plant cane.

Although the beetle may have a slight preference for the lighter soils, sugarcane on heavy lands has in many cases suffered more injury than that growing on lighter soils only a few fields distant. Over 50 per cent

of the sugarcane shoots have been killed by the beetles in fields on both types of soil.

NATURAL CONTROL. Owing to the great fluctuations in the number of beetles appearing from year to year, it is evident that natural control has a great influence on them. Many larvae and pupae are, no doubt, killed when the soil remains water-soaked for several days at a time. From evidence thus far obtained it seems that drought has little effect in controlling the beetles in Louisiana.

Plantation people state that skunks do a great deal of feeding upon adult beetles. Many excavations made by skunks or other animals of similar size have been found beside beetle-infested plants. The U. S. Biological Survey reports the crow, meadowlark, and bluebird as feeding upon the beetles. It seems likely that the grackle and red-winged blackbird also feed upon them.

The adult beetle is parasitized by the larva of a fly, *Sarcophaga helicis* Tns. The beetle larvae are also parasitized by another dipteron, *Microphthalma disjuncta* Wied. On August 5 and 6, 1931, 8 out of 23 larvae found were parasitized by this fly. No parasitized larvae were found later, however.

CONTROL METHODS. Observations indicate that the application of lime is of little or no value in controlling the sugarcane beetle. Alternate cuts of plant cane were given an application of 350 pounds of finely ground oyster-shell lime per acre in the plant furrow at the time of planting in the fall of 1930. On April 30 of the following year 7.2 per cent of these shoots were dead from beetle injury as compared with 7.9 per cent in the intervening cuts that were not limed. Hydrogen-ion determinations of soils gave little indication that beetle damage was affected by acidity or alkalinity of the soil.

Treatment of plant cane in the spring with commercial lime, oyster-shell lime, sulphur, borax, and calcium arsenate in varying amounts was tried. Judging from one year's results, none of these materials is of much value as a beetle control.

Hand collection of beetles has been tried on some plantations, but the economic value of this work is doubtful. A plantation laborer, paid 85 cents a day at present, collected 311 beetles in two days. One plantation paid one-half cent per beetle for all beetles collected.

The attraction of the adults to lights is too small to be of much value as a control. Small numbers of beetles were collected at lights in April and May. On many of the cool nights in April, at the time the beetles were causing heavy injury, none were collected after a gasoline lantern and automobile headlights had been operated for several hours at a time.

When released near a light some beetles were not attracted to it. On August 10 about 23 of the newly emerged beetles were collected at gasoline and automobile lights operated for one-half hour. On the 14th of September 17 *E. rugiceps* were collected at lights in one hour and fifteen minutes. In contrast with this result, 1,195 specimens of *Dyscinetus trachypygus* Burm., which closely resemble *E. rugiceps,* were collected on August 10 in one-half hour.

To determine the possibilities of varietal control of the beetles, dead and live shoot counts were made in replicated Latin square variety test fields. The percentage of dead shoots in light soil was: P. O. J. 36M, 17.83 per cent; P. O. J. 234, 20.51 per cent; C. P. 807, 23.21 per cent; Co. 281, 25 per cent; and P. O. J. 213, 25.56 per cent. In heavy black soil the dead shoots were, C. P. 807, 39.6 per cent; Co. 281, 43.4 per cent, and P. O. J. 213, 46 per cent. The preference of varieties by the beetle does not appear to be marked enough to warrant discrimination against any variety for this reason. Vigor and increased suckering ability are, however, very desirable in cane that has been injured by the beetles.

Since summer-planted cane gives a larger number of shoots the following spring than fall-planted cane, it would seem that summer planting would probably be of value in securing a good stand in spite of beetle injury. By permission of the Bureau of Plant Industry the following stand counts, made on April 30, are given on summer and fall planted cane:

Variety	Shoots per acre planted August 30	Shoots per acre planted October 1
P. O. J. 36M	28,710	11,880
P. O. J. 213	28,710	14,850
P. O. J. 234	35,640	20,295
C. P. 807	116,820	29,205
Co. 281	76,230	13,860

It will be seen that, with most of the varieties, beetles could kill one-half of the shoots from summer-planted cane and a better stand would remain than in an uninjured fall-planted cane field.

It is apparent that the plantation sod lands, both front and back,[3] are important sources of infestation. If these breeding grounds could be eliminated as such, the sugarcane beetles losses would be reduced. In the back lands, the encouragement of the growth of trees and heavy weeds by keeping down fires, together with reforestation, would lower beetle breeding to a great extent, as forested land is avoided by the insect.

The front pasture lands could be alternated so as to permit plowing

[3]In Lousiana, the "front" of a plantation is the relatively high land bordering on a watercourse, while the "back" is the low land near a swamp.

of the sod. If these lands could be put into cultivation, beetle breeding would be practically eliminated there. It would probably be of benefit during May to disk sod lands, otherwise untreated, so that these lands might be thus rendered less attractive to the beetles for egg laying.

Working plantation roadways and caring for ditch banks would do much toward eliminating these areas as breeding grounds. In the case of ditch banks, plowing or cultivation nearer the ditches in May and June would destroy much of the small grass in which the beetles breed.

TIMING THE SPRAY APPLICATIONS BY THE EMERGENCE OF THE CODLING MOTH

By LEONARD HASEMAN and PAUL H. JOHNSON

ABSTRACT

In the control of the codling moth (*Carpocapsa pomonella*) it is important that the spray applications be timed so that there will be a maximum of fresh spray coverage on the fruit and foliage when there is a maximum of worms entering the fruit. In Missouri we are using breeding cages and bait traps to follow moth and worm development through the spring, summer and early fall, and are timing the spray applications by actual moth emergence. Results show that equal or better control can be secured with from one to three fewer applications if they are timed to best advantage. Time-to-spray recommendations are received by every apple grower in the state.

Missouri's reputation as a fruit growing state was largely built around the "Big Red Apple." Until within comparatively recent years, Missouri ranked first in the number of bearing apple trees. Then came the San Jose scale, canker, and other pests, and along with them a great reduction in acreage of orchards, especially on marginal lands. While the early orchard spraying work was largely directed at the scale and canker worms, the codling moth soon became the outstanding apple pest in Missouri and for the past two decades the spray schedule for apples has been built around the codling moth.

Until the recent nation-wide upheaval of the codling moth occurred, Missouri apple growers had but little difficulty in controlling the pest. They ordinarily applied the cluster bud, the calyx, the curculio or 10-day cover spray, and usually one additional cover spray for the first brood of apple worms. Unless diseases or other pests proved serious, as a rule no spraying was considered necessary after the first of July. In those days growers were advised to time the cluster and calyx sprays by the bud and blossom development and to time the later sprays by the calendar. Some still advise such a procedure, calling for nine or ten

applications. Equal or better control can be secured with six or seven sprays where they are properly timed.

DEVELOPING THE METHOD. Careful codling moth breeding experiments have shown that the moths do not emerge from year to year either according to the calendar or with any definite reference to the blooming date of apples. The grower, therefore, cannot tell when the young worms are entering the fruit by simply referring to the calendar. Some years moths emerge and the worms begin to enter the fruit as much as two weeks later than normal. The individual growers, as a rule, are not in a position to accurately determine moth emergence, so the department of entomology has undertaken the task of determining this for each important apple growing center. The growers are assisting the department with this work and it is to be hoped that they may soon largely take over the breeding cage work.

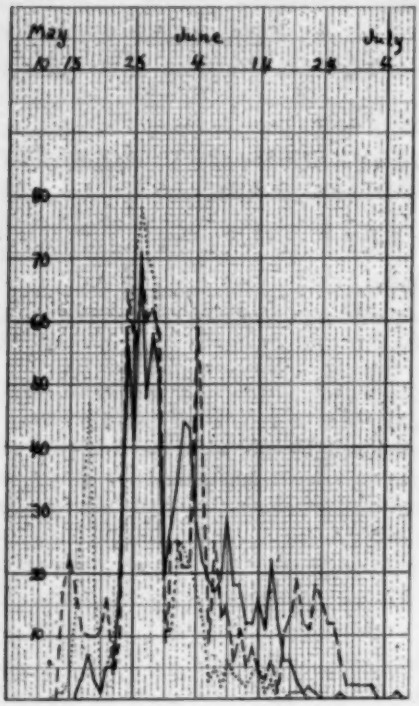

Fig. 53. Dotted line shows emergence of spring brood of codling moths in Central Missouri breeding cages. Broken line represents emergence of spring brood of moths from tree trunk cages at Columbia. Solid line represents emergence of spring brood of moths in North Missouri breeding cages.

Five years ago this department began its state-wide study of the yearly breeding activity of the pest. For the first few years only a few growers cooperated and only a few breeding cages were used. Each year since the work was begun additional growers have called for cages and have agreed to assist with the work. We have felt that in our campaign against the pest we must know just what it is doing throughout the entire season. Originally we depended primarily on the emergence of moths in the breeding cages for our records. Now, however, we are supplementing this data with daily bait trap catches and with emergence records in screen traps built around tree trunks to enclose large num-

bers of worms which cocoon naturally. This enables us to check our breeding cage records with the normal activity of the moths in the orchard and we find them agreeing very closely.

PLAN OF PROCEDURE. In the fall of 1930 nineteen commercial orchardists and one county agent agreed to handle breeding cages and report the emergence of codling moths. Six were in the distrtict around St. Joseph, two in the Kansas City area, two in the Waverly area, two at Columbia, two in North Central Missouri, two in the Hannibal area, two in the St. Louis area, one at Cape Girardeau, and one at Aurora. All the main orchard districts of Central and North Missouri were represented.

The Ozark area of South Missouri was under the direction of R. M. Jones, entomologist of the Missouri State Fruit Experiment Station, and he supplied similar spray information to the orchard men in that area from the field laboratory at Marionville.

The codling moth larvae are collected in September and October under bands, placed in a tight container with cocooning sticks in which they spin their winter cocoons. They are then sent to the various cooperators in small, wire breeding cages with instructions to wire the cages to the east side of the trunk of a representative apple tree in the orchard. The cages are made of galvanized screen wire in the form of a cylinder 4½ inches in diameter and 9½ inches tall. The cocooning sticks are 8 inches long and 1½ inches wide, grooved on both sides transversely. The grooves are ⅛ inch deep, ⅛ inch wide, and ¼ inch apart. Over the grooves are glued strips of celluloid the same dimensions as the stick, and over these, to darken the grooves, thin strips of wood are held in place by rubber bands. The number of larvae in each cocooning stick is recorded on the thin strip of wood. Approximately 100 larvae are contained in each breeding cage.

The cooperator reports the first emergence in the cage and continues to do so twice a week as long as moths emerge. A chart is kept at Columbia and at the correct time indicated by the emergence in the various districts "time-to-spray" letters are sent out to all the fruit growers in the state, giving the dates when the different applications should be made. This year spray letters were sent out for the first cover, the first brood peak spray, and a third cover for the first brood of worms. Later spray letters were sent out recommending two sprays for the July brood, and one for the August brood of worms.

Three cooperators, of their own accord, ran bait traps, and two of these sent in records of the catch, as well as the emergence data. A

number of the growers used bands, and some attempted to run the cages through the summer with varying degrees of success.

At Columbia during the winter six bands were left on the trees and caged to check the accuracy of the regular breeding cage emergence. Ten cages, thirty-three bait traps, and one hundred bands were used at Columbia.

This fall ten additional orchard men have received cages, seven in Southeast Missouri, two in the St. Louis district, and one in the Hannibal area. Eight cooperators have restocked their cage with larvae from their own orchard and five of these have received an extra cage stocked with larvae from Columbia to see if collecting and mailing the larvae from Columbia has any effect on the time of emergence.

INTERPRETING THE DATA AND DISTRIBUTING RECOMMENDATIONS ON SPRAYING. A train dispatcher must have before him at all times a record showing the position and the activity of every train and every crew in order that he may accurately and safely dispatch orders. In our drive on the codling moth in Missouri we are using similar methods. If we have before us accurate data showing when the first moths of the spring brood emerge in each apple growing center, and we have the daily weather records, we can tell the growers when their first worms may be expected and, therefore, when they must get their sprays on. As the season advances and the daily emergence of moths increases we are able to chart this, eventually reaching a peak, and then a decline in the number of moths to the point where second brood moths begin to appear. Weather conditions interrupt the steady rise and decline of moth emergence but we have found that, as a rule, these interruptions are felt to about the same degree all over the state. On occasions, however, local sudden drops of temperature often with late spring snow squalls may check moth activity in one section and not over the rest of the state. Then too, the elevation and the slope of the land on which the orchard is planted will have some influence on the development of the pest. The analyzing of the data and the preparation of state-wide recommendations every ten days or two weeks throughout the season is, therefore, a considerable undertaking, particularly since each report must be in the hands of the growers a week or more before the spray is to be applied and since we are dealing with a crop running into several million dollars.

We are particularly anxious that all our growers shall time their first brood sprays properly. If they succeed in controlling the first brood of worms, the season's battle is largely won. If they fail to hold the first brood, on the other hand, the battle is practically lost. We have made special effort, therefore, to get all the accurate data possible on the

activity of the first brood moths and worms from all the important orchard centers of the state. After the middle of July, as a rule, we can expect moths and worms to appear in greater or less abundance continuously until well into September. During July and August it is much more difficult for the growers to run the breeding cages and give us accurate data on moth emergence, so we depend more on the bait trap records in determining the periods of greatest moth activity. In timing the spray applications for July and August an effort is made not merely to keep on a continuous coverage but to insure a maximum of spray coverage when the greatest number of worms are entering the fruit.

At the opening of the spray season the growers are urged to keep in mind the fact that they are preparing to protect their crop against not only the codling moth but also various other insect pests and plant diseases. They are urged to use their own judgment in modifying our recommendations as to dates of application and spray solutions to better suit their local conditions. Many of the growers are so completely sold on the state-wide "time-to-spray" recommendations that without these warnings they might completely overlook local less important troubles.

The early applications, including the dormant or delayed dormant, the cluster bud and the calyx sprays, are timed by weather or bud and blossom development. The growers are advised in advance to time these early sprays to best suit local conditions. Often the first cover spray is also applied well in advance of the first appearance of apple worms. If the season is favorable for apple scab and curculios and the codling moths are late in emerging, the first cover spray is applied in advance of worms, or in from seven to fourteen days after the calyx spray. When possible, however, it is timed so that the fruit will be freshly covered with spray when the young worms first begin to hatch. The second cover spray then is applied just ahead of the peak of first brood worms. Where worm control has not been satisfactory in the past, we advise the growers to increase the amount of arsenate of lead in this spray, or to include a sticker. The number of additional sprays for the first brood worms will depend on how promptly all first brood moths emerge. In most cases we have found that one additional application made in about two weeks after the peak cover spray will protect the fruit from the late first brood worms. However, the breeding cage and bait trap records will show how long moths continue to emerge and when any considerable number of worms are hatching at that stage of development of the young fruits we feel that the interval between sprays should not exceed two weeks.

Normally there is a period of several days between the last important emergence of first brood moths and the first appreciable emergence of

second brood moths. When most or all of the first brood moths have emerged we restock the old cages or keep new cages continuously stocked with matured worms throughout the rest of the season. After July the overlapping of broods with us necessitates continuous observations and stocking of cages in order to determine fully the later activity of the pest. The individual grower is usually not able to give the time to the work, so after the first of July the bait trap records become increasingly important in following the activities of the pest in the outlying apple growing sections. Our records of summer moth activity this year indicated that a spray application should be made the middle of July, another the last of July, and a third around the middle of August, and our growers were advised to time their late sprays accordingly.

In this work it is not our purpose necessarily to reduce the number of spray applications but rather to help the growers time the applications for best worm control. Actually we are finding that one or two less applications timed according to moth activity gives equally as good control. Under Missouri conditions, the recent abundance of apple worms has been brought about largely, we believe, by the tendency of the moth to vary from its earlier normal yearly cycle with the result that most growers were not timing the spray applications to match real worm entrance. Other factors had their influence but our conviction that the sprays were not being properly timed is borne out by our more recent results.

Along with the systematic timing of the spray applications, we are also stressing other practical methods of moth reduction, including the use of bands, the scraping of the tree trunks, orchard sanitation, and packing house screening and treating of used baskets, boxes, barrels and other equipment. With our growers convinced that this program must be carried out and with most of them prepared to handle the spray residue problem, barring new unforeseen developments, there is no reason why they cannot keep the pest under control in this state.

General Results. The emergence cages in each district generally gave practically the same results, though in some cases one would run a few days behind the others. Figures 53 and 54 show graphically the results in Central and North Central Missouri. In the graph for Central Missouri the districts around St. Louis, Columbia, Waverly and Kansas City are grouped together, and the results are shown by the dotted line. The broken line gives the emergence results from the caged tree bands at Columbia. Figure 54 shows the bait trap catch at Columbia.

This summer we had only one cage in Southeast Missouri, and one in Southwest Missouri, and the results from these cages indicated that moth

development in Southwest Missouri was about the same as in Central Missouri or possibly a few days earlier, while in Southeast Missouri it was from ten days to two weeks ahead of Central Missouri.

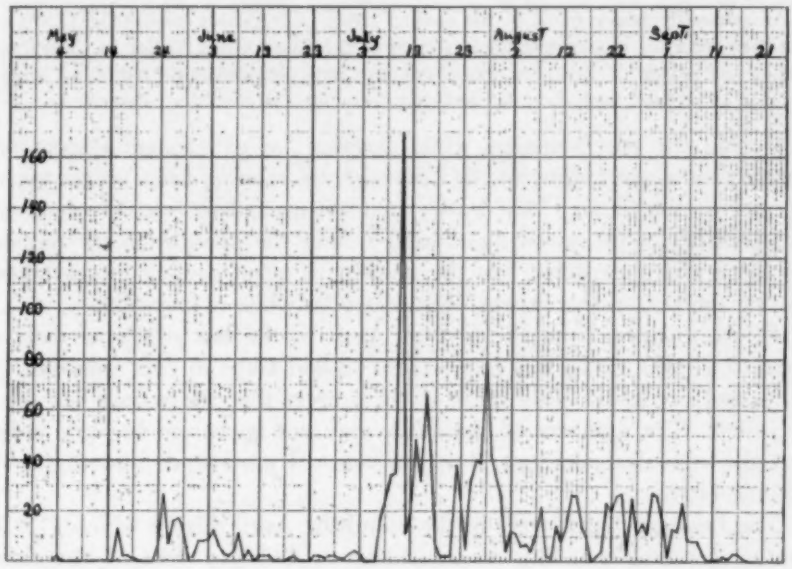

FIG. 54.—Bait trap catch of codling moths at Columbia, Missouri.

The orchard men in general are not only anxious to receive the spray information but also want a cage in their orchard. We could have placed several more cages this fall if they had been available. Even those growers, who hesitate to forsake the idea of spraying continuously, request that we supply them with cages and the "time-to-spray" information. Some growers follow the spray recommendations but also put on extra sprays in addition to those recommended.

Our spray blocks show that we get just as good control and often better when we apply five and six cover sprays according to moth emergence than when we put on from seven to nine sprays at 10-day intervals.

ORCHARD SANITATION AND THE CODLING MOTH

By GEORGE S. HENSILL, *University of California*

ABSTRACT

An unusually heavy flight of the codling moth (*Carpocapsa pomonella* (Linn.)) has been recorded in a certain apple section of the Santa Clara Valley in California during the season of 1931. Records of the same were obtained by the use of bait traps. Lack of orchard sanitation definitely accounts for the conditions described.

During the past summer, while carrying on experimental spraying for control of the codling moth (*Carpocapsa pomonella* Linn.) in the apple district of the Santa Clara Valley in California, bait traps[1] were used in checking on the moth flights and timing the application of sprays. So large and unexpected was the number of adult codling moths taken during the season that it was deemed worth while of mention.

In six months, from the first of April to the last of September, a total of 23,900 moths was taken from 12 bait traps in two immediately adjoining orchards. This catch is the largest that the writer has seen recorded. The numbers of the catch may not appear to be very large but the statistical analyses show an unusual emergence and flight of codling moths.

The heaviest flights were in the month of April during which 11,917 moths were taken. This is equivalent to 49.8 per cent of the total season's catch. During one week from April 15 to 21, inclusive, a total of 6,131 moths was taken, which is over one-half of the catch for the whole month. (See emergence chart, Fig. 56.)

The average daily catch for the whole season was 130 moths per day in the 12 bait traps, which is an average of practically 11 per trap per day. An average of 11 moths per trap would be considered dangerous in most any orchard for even a single day, so that an average of 11 per trap per day over a six months period would make a most serious situation from the standpoint of codling moth control. It may be seen from the emergence chart (Fig. 56) that a very difficult situation did exist in regard to spray application.

An insight into orchard conditions existing in this case will explain the extremely large moth population and serve also as an orchard cleanliness warning to other orchardists. This particular orchard section is an old one and has long been known for heavy moth populations but previous records are not to be compared with the high total of the present records.

[1]The bait traps used were ordinary pudding pans 10 inches wide at the top by 3½ inches deep. The syrup used was Fleischmann's Special Diamalt made up to a 5 per cent solution (1 pint syrup to 19 pints water plus 1 pulverized yeast cake).

The most important factor of orchard cleanliness is the removal of wormy fruit from the orchard and its destruction as soon as possible. In orchard A(Fig. 55) the fruit culled about 60 per cent on an average, due to worminess during the season of 1930. At picking time the fruit was sorted in the orchard, the good fruit was hauled out and the wormy

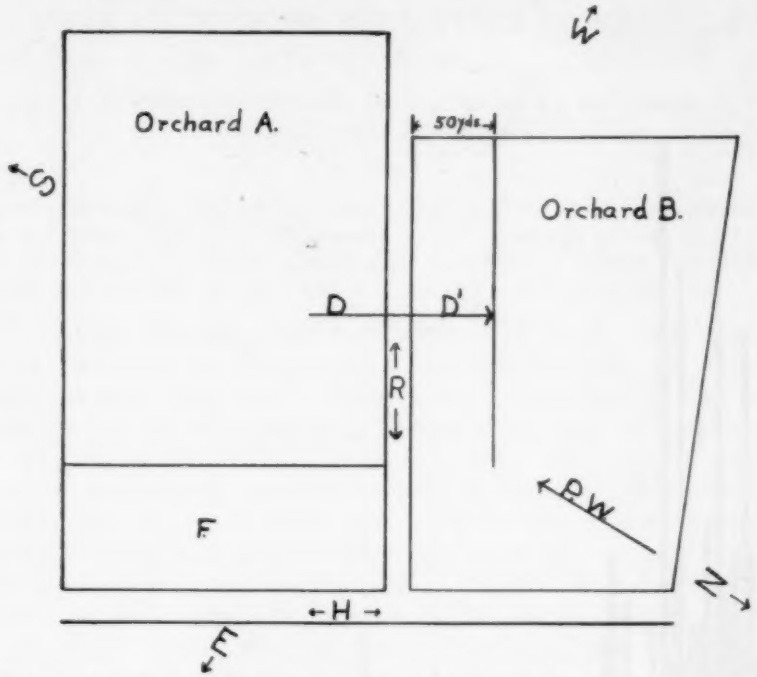

Fig. 55.—Diagram showing relative position of the two orchards. D-D'—Direction of moth flight from Orchard A into Orchard B; P. W.—Direction of prevailing winds which usually subside by sunset; R.—Driveway about 25 feet wide; F.—Field; and H.—Highway.

fruit was dumped on the ground around the trees to rot. It was quite common to find as high as 300 larvae in pupation under a single 3-inch, two layer burlap band. As a result, the moth flights were unusually heavy during the 1931 season and the control situation was very difficult.

In the problem of orchard sanitation there are also other factors influencing the size of the codling moth population. Orchard A (Fig. 55) in particular is poorly kept, receiving too infrequent pruning and cultivation. This coupled with frequent irrigation makes an ideal growth of weeds, which favors pupation and a consequent increase in numbers of moths. In this same orchard the trees have never been sufficiently

scraped and the rough bark and dead pruning cuts make ideal locations for pupation. There is also a decided lack of proper and sufficient banding in both orchards. Orchard B (Fig. 55) is well pruned and the rough trunks are well scraped but it is difficult to compete with the large

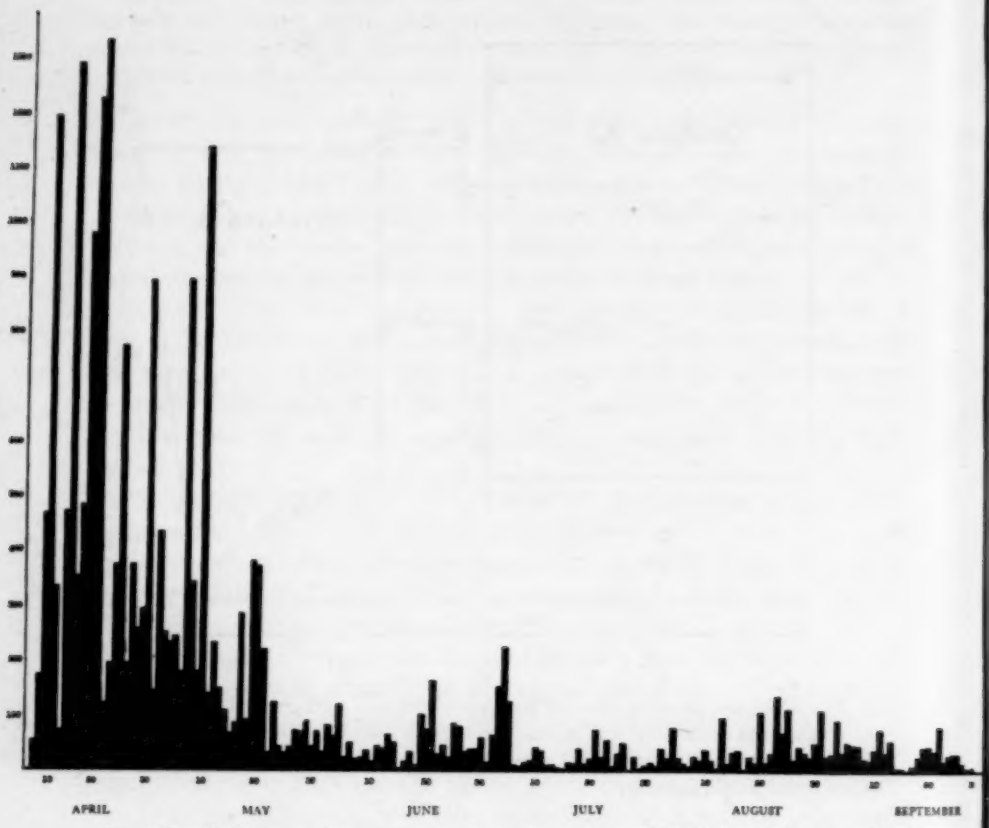

Fig. 56.—Codling moth emergence chart for season of 1931 in the two orchards under consideration. Numbers on ordinate (100-1300) represent total daily moth catches.

number of moths from the poorly kept orchard, especially in the adjoining parts of the two orchards.

From the described orchard conditions and lack of orchard sanitation on the part of one grower, it may easily be seen that he, as well as his neighbor, has a great deal to contend with due to negligence which might

be avoided. A different situation would certainly exist here if a few important factors of orchard sanitation were put into effect.

Orchard sanitation does pay and growers would profit considerably if it were properly and conscientiously carried out.

RELATIVE TOXICITY OF SOME DUSTS TO *CARPOCAPSA POMONELLA*

By R. E. Barrett, *Entomologist Saticoy, Ventura Co. and Moorpark Walnut Growers' Associations*

Abstract

Barium fluosilicate and synthetic cryolite are the only fluorine compounds of those tested which show promise for use in controlling the codling moth on walnut. Talc of 400 mesh furnishes better protection than lime. A dust of 35% barium fluosilicate or synthetic cryolite and 65% talc of 400 mesh is recommended.

The English Walnut is extremely sensitive to water soluble arsenic and for the control of codling moth a basic lead arsenate must be used having not more than 0.25% arsenic in water soluble form. This material, the toxicity of which is considerably less than standard lead arsenate, has not proven altogether satisfactory with regards to the protection it affords the crop. The problem of testing out other materials which might be more toxic to the codling moth and not injure the foliage was undertaken in 1930 and continued during 1931.

To determine the tolerance of the walnut tree to various fluorine compounds trees were dusted, at the rate of 2 lbs. to the tree, with the following materials: barium fluoride, barium fluosilicate, calcium fluoride, synthetic cryolite, lead fluoride, magnesium fluosilicate, sodium fluoride, sodium fluosilicate, and zinc magnesium fluosilicate. Barium fluoride, magnesium fluosilicate, sodium fluoride, and zinc magnesium fluosilicate entirely defoliated the trees and killed the current year's wood. Sodium fluosilicate burned the tips and margins of the leaves and the husk of the nuts although it did not cause very severe defoliation. Barium fluosilicate and synthetic cryolite were selected for additional study. Lead fluoride was eliminated by price and calcium fluoride by reason of its very low toxicity as shown by Marcovitch (1928).

A concept of the solubility of some of the materials used can be gained from the following table. The figures given are the grams per 100 cc. solid material found after the evaporation of the clear liquid from a flask which had received 250 cc. of rain water and 2.5 or 5 grams of the material to be tested. Some of these substances hydrolize and seem

fairly soluble. As the materials tested were not C. P., the results are open to question.

	Grams per 100 cc.	
Sodium fluoride	1.6356	Burn
Sodium fluosilicate	0.6532	Burn
Barium fluoride	0.1074	Burn
Lead fluoride	0.0514	No burn
Cryolite, synthetic	0.0438	No burn
Barium fluosilicate	0.0254	No burn
Calcium fluoride	0.0038	No burn

Walnuts were cut and the stems placed in bottles filled with tap water. These were placed in a well lighted laboratory. Freshly hatched larvae were obtained in the manner described by Smith (1926). All larvae were descendents of larvae which had the previous generation fed on apple. Because of the small number of larvae surviving on walnuts dusted with some of the materials and the difficulty of interpreting results, apples were used to supplement part of the test as they did not have as great a resistance to codling moth injury as the walnut. Stems and calyxes were covered with petroleum jelly so that the larvae could not escape and entries could only be made through the sides where there was small likelihood of overlooking larval work. Dust was applied with a small hand duster as the fruit was revolving.

Petri dishes filled with water were placed under the nuts to catch any larvae that fell from the nuts. The dishes were not large enough to catch all the larvae and most of the larvae unaccounted for fell outside the dish. Enough were obtained, however, to give the relative frequency with which this happened. It was noted during the experiment that larvae liberated on nuts dusted with material of fine mesh, as talc of 400 mesh and synthetic cryolite, were so hindered in their movements that they frequently fell from the surface of the nut. Approximately 7,000 freshly hatched larvae were used in this work. In the following tables the number given as liberated is the number originally liberated minus the number found dead in the petroleum jelly which amounted to 7% of the total.

	Host Walnut Check		
Liberated	981		Ratio injuries to liberations
Live	199	20.3%	876 : 981
Dead on surface	248	25.2	1 : 1.12
In water	232	23.6	Ratio entrances to stings
Unaccounted for	302	30.8	352 : 524
		99.9%	1 : 1.49
Injuries			
Entrances	352		
Stings	524		

Lime

Liberated	474		Ratio injuries to liberations
Live	63	13.3%	262 : 474
Dead on surface	164	34.6	1 : 1.82
In water	127	26.8	Ratio entrances to stings
Unaccounted for	120	25.3	102 : 160
			1 : 1.57
		100.0%	
Injuries			
Entrances	102		
Stings	160		

Talc 180 mesh

Liberated	501		Ratio injuries to liberations
Live	63	12.6%	261 : 501
Dead on surface	145	28.9	1 : 1.92
In water	197	39.4	Ratio entrances to stings
Unaccounted for	96	19.3	106 : 155
			1 : 1.46
		100.2%	
Injuries			
Entrances	106		
Stings	155		

Talc 250 mesh

Liberated	339		Ratio injuries to liberations
Live	31	9.2%	106 : 339
Dead on surface	119	35.1	1 : 3.19
In water	125	36.8	Ratio entrances to stings
Unaccounted for	64	18.9	38 : 68
			1 : 1.79
		100.0%	
Injuries			
Entrances	38		
Stings	68		

Talc 400 mesh

Liberated	436		Ratio injuries to liberations
Live	34	7.7%	242 : 436
Dead on surface	159	36.5	1 : 1.60
In water	152	34.8	Ratio entrances to stings
Unaccounted for	91	20.9	63 : 179
			1 : 2.84
		100.0%	
Injuries			
Entrances	63		
Stings	179		

Lead arsenate (basic)

Liberated	492		Ratio injuries to liberations
Live	0	0.0%	17 : 492
Dead on surface	344	70.0	1 : 28.94
In water	108	21.9	Ratio entrances to stings
Unaccounted for	40	8.1	0 : 17
		100.0%	

Injuries	
Entrances	0
Stings	17

Barium fluosilicate

Liberated	360		Ratio injuries to liberations
Live	0	0.0%	17 : 360
Dead on surface	257	71.4	1 : 21.20
In water	77	21.4	Ratio entrances to stings
Unaccounted for	26	7.2	0 : 17
		100.0%	

Injuries	
Entrances	0
Stings	17

Cryolite, synthetic

Liberated	710		Ratio injuries to liberations
Live	1	0.1%	50 : 710
Dead on surface	347	48.9	1 : 14.20
In water	295	41.5	Ratio entrances to stings
Unaccounted for	67	9.5	2 : 48
		100.00%	1 : 24

Injuries	
Entrances	2
Stings	48

HOST—APPLE

Check

Liberated	439		Ratio injuries to liberations
Live	254	58.0%	302 : 439
Dead on surface	52	11.8	1 : 1.45
In water	56	12.7	Ratio entrances to strings
Unaccounted for	77	17.5	298 : 4
		100.0%	1 : 0.013

Injuries	
Entrances	298
Stings	4

Lead arsenate (basic)

Liberated	225		Ratio injuries to liberations
Live	3	1.3%	65 : 225
Dead on surface	117	52.0	1 : 3.46
In water	69	30.7	Ratio entrances to stings
Unaccounted for	36	16.0	59 : 6
		100.0%	1 : 0.102

Injuries	
Entrances	59
Stings	6

Barium fluosilicate

Liberated	330		Ratio injuries to liberations		
Live	0	0.0%	27	:	330
Dead on surface	191	57.9	1	:	12.21
In water	129	39.1	Ratio entrances to stings		
Unaccounted for	10	3.0	7	:	20
		100.0%	1	:	2.858
Injuries					
Entrances	7				
Stings	20				

Cryolite, synthetic

Liberated	708		Ratio injuries to liberations		
Live	1	0.1%	81	:	708
Dead on surface	290	41.0	1	:	8.74
In water	317	44.8	Ratio entrances to stings		
Unaccounted for	100	14.1	59	:	22
		100.0%	1	:	0.372
Injuries					
Entrances	59				
Stings	22				

Contrasting lime and talc of the three different meshes with the check, it is apparent that some protection is obtained from each of these materials. In the talc series it seems that fineness of mesh has considerable bearing on the protection afforded the nut from injury. Talc of 400 mesh gives slightly less than twice the protection that lime does.

Interpretation of the results obtained with the lead arsenate and the two fluorine compounds is difficult on the walnut, but on the apple it is conclusively shown that lead arsenate is the inferior insecticide and barium fluosilicate the superior insecticide, giving approximately four times the protection to the nut that basic lead arsenate furnishes. The standard dust used for codling moth on walnuts is composed of 35% basic lead arsenate and 65% lime. From results obtained in the laboratory a dust of 35% barium fluosilicate and 65% talc of 400 mesh should give much better results. Synthetic cryolite could be substituted for barium fluosilicate with but small loss in toxicity. A 35/65 mix would give a dust of the correct physical properties.

ACKNOWLEDGMENT. Acknowledgment is due to R. Buckner for his assistance in manipulating the larvae and making counts of the larvae and injuries.

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OBSERVATIONS ON THE DISTRIBUTION OF HIBERNATING ORIENTAL FRUIT WORMS[1] [2]

By L. F. STEINER[3]

ABSTRACT

The efficiency of early spring cultivation and the peach tree borer paradichlorobenzene treatment in oriental fruit worm control is dependent upon the distribution of the surviving hibernating population on and about the tree. Examinations of ten trees in southern Indiana indicate that this distribution is extremely variable and subject to such factors as variety, ripening date, amount of rough bark on the tree, debris on the ground, and winter mortality. Elbertas were found to have 100 per cent of their hibernating larvae on the tree, Krummels averaged 85.6 per cent, Fleener Clings 20 per cent, and White Heath Clings 18.6 per cent. Small bits of weed stems held more hibernating larvae than anything else under the trees. In 1929–1930 less than one per cent of the larvae hibernating above the snow line survived parasitism and low temperatures. Cultivation and the paradichlorobenzene treatment under such climatic conditions should be effective as partial oriental fruit worm controls. Under normal Indiana conditions, however, they appear useless when applied to early ripening varieties or to any variety when much of the trunk is covered with rough bark.

Thorough cultivation during the dormant season and the peach tree borer paradichlorobenzene treatment are frequently recommended to peach growers as control measures that can profitably be employed against the oriental fruit worm.

These recommendations are often made without taking into consideration the fact that their effectiveness is dependent directly upon the distribution of the hibernating population on or about the tree. If they are to be of value it is obvious that most of the surviving larvae must be located on the ground or at the base of the trunk.

The investigations reported herewith were conducted at Bedford and Vincennes, Indiana, by the Purdue University Agricultural Experiment Station during the winter of 1929–1930. Although of necessity limited in scope, they indicate that the distribution of hibernating oriental fruit worms is extremely variable and is dependent upon several factors, and they emphasize the importance of considering these factors before recommending the above mentioned practices to the peach grower. Further investigations conducted along this line over a period of years should be of considerable value.

[1] *Laspeyresia molesta* Busck.

[2] Contribution from the Department of Entomology, Purdue University, Agricultural Experiment Station, Lafayette, Indiana.

[3] Assistant in Entomology 1927–1930.

In order to study the distribution of hibernating larvae and the more important factors which affect this distribution it was necessary to first locate all hibernacula on or about trees growing under different sets of conditions.

Between October 25, 1929 and March 15, 1930, a thoroughly minute examination of the entire surface of ten trees was made. Every possible cocooning place on the tree from twig tip to base of trunk was searched. Under each tree a quarter sector of the soil area was measured off and everything to a depth of two inches pulverized by hand and carefully examined. The entire soil population under each tree therefore approximated four times the number found in that sector. When mummied fruits were not uniformly distributed under the tree, all were picked up and examined. Each tree required from one to three days' time.

The distribution of oriental fruit worm hibernacula containing living, parasitized, or dead larvae on each of the ten trees is summarized in Table 1. Larvae maturing on these trees were subjected to four different sets of conditions and the trees representing these are grouped accordingly.

TABLE 1. DISTRIBUTION OF HIBERNATING ORIENTAL FRUIT WORMS ON AND ABOUT TEN TREES AT BEDFORD AND VINCENNES, IND., DURING WINTER OF 1929-30

		Under tree		On tree						Per cent	
Tree No.	Mummies	On other debris and soil*	Total	At soil level	1–8″ up	8″–2′ up	2–8′ up	Above 8′	Total	Under tree	On tree
1	24	24	48	6	3	2	10	5	26	64.0	36.0
2	25	108	133	6	2	3	9	4	24	84.7	15.2
3	7	112	119	3	3	2	8	3	19	86.2	13.7
Ave.	18.6	81.3	100	5	2.6	2.3	9	4	23	81.3	18.6
4	0	72	72	0	3	3	1	2	9	88.8	11.1
5	4	40	44	0	3	11	5	1	20	68.7	31.2
Ave.	2	56	58	0	3	7	3	1.5	14.5	80.0	20.0
6	8	8	16	1	43	40	101	29	214	6.9	93.0
7	4	84	88	13	109	81	56	17	276	24.1	75.8
8	4	0	4	2	17	44	77	13	153	2.5	97.4
Ave.	5.3	30.6	36	5.3	56.3	55	78	19.6	214.3	14.3	85.6
9	0	0	0	0	1	3	0	0	4	0	100.0
10	0	0	0	0	0	1	0	0	1	0	100.0
Ave.	0	0	0	0	0.5	2	0	0	2.5	0	100.0

*These figures are the product of the number found in the quarter sector multiplied by four.

Trees 1, 2, and 3 near Bedford, Indiana, were of the White Heath Cling variety, ripening late. All were six years old making rapid growth, averaging 13 x 15 feet in height and diameter, and had produced a moderate crop which was severely infested. They were located on well drained clay loam soil which had been cultivated during the summer

and sown to rye. Very little rough bark and no coarse debris was present. The number of mummies found under each tree averaged 178. Of the larvae found under the tree exclusive of those on mummied fruits, 39 per cent were within 6 inches and 96 per cent were within 5 feet of the trunk. Of the entire population approximately 12 per cent were on the tree above the level which would be reached by a paradichlorobenzene mound. Half of these had cocooned deep in pruning stubs or in the pith of one-half inch branches previously pruned back. Since coarse debris was absent under the tree, two-thirds of the larvae not on mummies were found in bits of weed stems seldom over one-eighth inch in diameter and two inches long. Others were found in timothy roots, bits of corn stalks, and attached to clods of earth, bark, or small broken twigs. Debris of any kind under these trees was so scanty that nearly all was found occupied. Apparently it was preferable to the mummied fruits.

Since the oriental fruit worm made its first appearance in this orchard in 1929, all empty summer cocoons were counted separately. These averaged 103 per tree of which number 84 per cent were on the tree itself. About two-thirds of the latter had been spun between peach stem and twig and remained on the stem when the fruit was removed. Summer cultivation in this orchard therefore would be of little value from the control standpoint. Early spring cultivation, immediate removal of fallen fruit, and the paradichlorobenzene treatment, if thoroughly done, in orchards which this type tree represents should destroy 88 per cent of the overwintering brood, leaving 12 per cent on the tree, of which number half are well protected and the other half more or less exposed to birds, parasites, dormant sprays, and extremes in temperatures.

Trees 4 and 5, also near Bedford, were of the Fleener Cling variety, ripening late, and were 16 years of age. They averaged 14 x 16 feet in height and diameter and each had about four square feet of rough bark surface on the trunk. The 1929 infestation was severe. Each tree bore a full crop. The soil was a heavy clay loam, poorly cultivated and with an abundance of dead weeds. Other debris was scarce. Fallen fruit had not been removed, there being an average of 160 mummies under each tree. Practically the entire soil population had cocooned in small bits of weed stems. Not more than 16 per cent of all the larvae found were above the top of the paradichlorobenzene mound.

Trees 6, 7, and 8 of the Krummel variety, ripening very late, were located near Vincennes on very sandy soil. These were mature, size 18 x 20 feet in height and diameter, with rough bark covering nearly 30 square feet of limb and trunk surface. All bore a full crop which was

severely infested. No fallen fruit had been removed. Paradichlorobenzene was applied at the base of the trunk before all larvae had matured. The soil was well cultivated during the summer and entirely free from debris except under tree number 7 where there were many weed stems and bits of wood. Mummies averaged 327 per tree. Over 85 per cent of the hibernating population was on the tree. Although about one-fourth of these had cocooned below the 8 inch level few were affected by the paradichlorobenzene since they spun up at the surface of the mound after it had been made. Under these conditions cultivation and the paradichlorobenzene treatment would be useless.

Trees 9 and 10 were of the Elberta variety located near the above mentioned Krummels and of about the same size and age. They produced an average crop which was moderately infested. Only about one-half as much rough bark as on the Krummels was present. The soil, however, was covered with a mat of weeds and about 80 mummied fruits were under each tree. All larvae were on the tree, most of them above the level of the paradichlorobenzene mound.

Probably the most important factor which determines whether the larvae about to hibernate will cocoon on or away from the tree is the location of the larva when it reaches maturity. If it matures and leaves a twig or fruit on the tree its chances of finding suitable cocooning quarters upon the tree are much greater than if it emerged from a fallen peach. Only a small percentage of the larvae maturing in Elberta peaches or in earlier varieties hibernate. If they mature in twigs after peach harvest as probably occurred on trees 9 and 10, and cocooning quarters are available, most of the hibernating population will be on the tree regardless of the amount of debris underneath. With the late maturing varieties the distribution is affected more by the presence or absence of suitable cocooning quarters in either location. If the fallen fruit is not removed before the larvae emerge from it they will be forced to cocoon on the ground unless they can reach the tree. In the presence of satisfactory debris their chances of reaching the trunk are greatly diminished. Those emerging from twigs or from fruit still on the tree, if suitable cocooning quarters are not available, may eventually reach the ground. A few larvae will spin loose in the soil. There was more of a tendency to do this on the clay loam than on the sandy soil. Larvae readily cocoon on the trunk at the surface of the soil, especially when debris and rough bark are scarce as on trees 1, 2, and 3. With trees 6, 7, and 8 the scarcity of weed stems and other debris on the soil caused many of the larvae to cocoon at the surface of the paradichlorobenzene mound 6 to 8 inches above the base of the trunk.

Climatic conditions and parasitism during the overwintering period may have considerable effect upon the distribution of the surviving individuals.

During the winter of 1929–30 three sudden and extreme drops in temperature occurred which resulted in a large mortality among hibernating oriental fruit worms. The minimum temperature reached was —20° F. at which time there were several inches of snow upon the ground.

When the examinations on trees 4 and 5 were made in February and March, of the larvae on the tree 72 per cent were dead and 20 per cent parasitized. Of those on the ground only 7 per cent were dead and 7 per cent parasitized. On trees 6, 7, and 8 approximately 70 per cent of the hibernacula contained dead larvae, 20 per cent parasites, and 10 per cent living larvae. Only one-tenth of the latter were above the snow line. Several species of parasites were represented, more than 50 per cent of them surviving. Of the soil population under these trees 37 per cent were dead, 26 per cent parasitized, and 37 per cent alive. With such a low survival above the snow line, thorough disking and the application of the paradichlorobenzene treatment should be effective.

In normal seasons, however, it would appear that these treatments could be practiced to advantage only on late maturing varieties where the trees were young or where litttle rough bark was present. They would appear to have little value on early varieties and on late varieties where much rough bark was present on the trunk. Since most of the soil population cocoons near the trunk, cultivation where employed must be extremely thorough.

STUDIES ON THE HOST PLANTS OF THE EUROPEAN CORN BORER, *PYRAUSTA NUBILALIS* HUBNER, IN SOUTHEASTERN MICHIGAN[1]

By F. F. Dicke, *U. S. Bureau of Entomology*

Abstract

Data are presented showng the extent of European corn borer infestation in economic plants and weeds in southeastern Michigan from 1927 to 1929, inclusive.

The European corn borer (*Pyrausta nubilalis* Hübner) has shown somewhat different habits in the area extending from western New

[1]The writer wishes to acknowledge with thanks the supervision of these studies by Dr. Philip Luginbill, in charge of the Station at Monroe, Michigan. Thanks are also due to Prof. H. T. Darlington of Michigan State College for determination of plant specimens and the verification of others the identity of which he was in doubt.

England to northern Indiana and southward to the Ohio River, where only a single generation exists annually, than in eastern New England in that the insect has confined itself almost entirely to corn for its host.

In eastern New England, where two generations occur annually, some 200 species of plants have been found infested by this insect (*1, p. 63*). The data available at the present time indicate that the number of specific plants attacked in the western area, previously mentioned, is considerably less than this. Practically all infestations in hosts other than corn have been confined to weeds and crop plants in or contiguous to cornfields.

In 1927 host-plant studies were begun in the more heavily infested areas in Michigan with the following objects in view: (a) to determine the extent of infestation in weeds, both within and outside of cornfields; (b) to learn the possibility of attack on economic plants other than corn, and its extent; and (c) to force infestations in weeds and crop plants, returning the progeny of each generation to the same host the ensuing year in order to determine (1) the establishment and survival, (2) the longevity of the species on the respective hosts in the absence of corn and whether or not there is any degeneration, and (3) any change in the life cycle.

UNCULTIVATED HOST AND SHELTER PLANTS OF THE EUROPEAN CORN BORER. All of the investigations of uncultivated host plants in the field have been confined to weeds in and about cornfields.

Along the west shore of Lake Erie sufficiently remote from corn to prevent larval migration, ladysthumb (*Polygonum persicaria*), big ragweed (*Ambrosia trifida*), cocklebur (*Xanthium* spp.), bull thistle (*Cirsium lanceolatum*), goldenrod (*Solidago* spp.), parsnip (*Pastinaca sativa*), lotus (*Nelumbo lutea*), elecampane (*Inula helenium*), and cattail (*Typha latifolia*) have been extensively examined, but no infestations by either eggs or larvae of the corn borer have as yet been recorded.

In cornfields, pigweed (*Amaranthus retroflexus*), ladysthumb (*Polygonum persicaria*), cocklebur (*Xanthium* spp.), big ragweed (*Ambrosia trifida*), common ragweed (*Ambrosia elatior*), groundcherry (*Physalis* spp.), lambsquarters (*Chenopodium album*), barnyard grass (*Echinochloa crusgalli*), Canada thistle (*Cirsium arvense*), beggarticks (*Bidens frondosa*), and velvetleaf (*Abutilon theophrasti*) have commonly been found infested. In addition to these, swamp aster (*Aster puniceus*) and tall white aster (*Aster paniculatus*) occurring along fence rows have occasionally been found to harbor larvae in the fall and spring.

There is no record of egg deposition on any of the above-named

plants in this area. With the exception of the two species of asters, early larval stages have been taken from all of the above-named species and, where the stems were of sufficient size to contain them, full grown larvae were frequently found.

It is generally accepted that infestations in plants other than corn, in the western area, are brought about almost entirely by larval migration from corn, the hosts serving merely as food and shelter incidentally. In comparison with the total larval population in corn, that found in weeds is almost negligible.

Extent of Infestations in Economic Crop Plants. The observations on the susceptibility of various economic crops to attack by the European corn borer were made in plots of approximately 1/60 acre in size. The plots were in series adjoining one another and had corn plots bordering them on at least one side with an intervening space of 7 feet serving as a barrier to check larval migration.

In 1927, all of the plots were examined for eggs on July 5, 12, and 19. One egg mass was found on buckwheat but no larvae became established from this mass. Later examinations showed leaf feeding on broomcorn and amber sorghum and infestations of 8 and 4 per cent, respectively, with an average of one larva per infested plant. One larva, probably migrant, was taken from each of the following plots: sunflower, buckwheat, and lettuce.

In 1928, the plots were examined for egg masses on July 16, shortly after maximum oviposition had occurred on corn, with negative results. Dissections at the close of the season revealed a 1 per cent infestation in hemp and broomcorn, respectively. The infestation in the hemp was apparently due to larval migration, as this plot had its rows alternated with heavily infested corn.

In 1929, examinations for eggs were made on July 6 and 17. Eggs were abundant on broomcorn millet throughout the oviposition period, and common on broomcorn, sorghum, and sudan grass. The plants in these plots were at a stage of development that was very attractive to ovipositing moths.

There was intense larval migration within and from the broomcorn millet plot due to the early ripening and collapsing of the plants. Buckwheat in a plot adjoining broomcorn millet served as an acceptable host to the migrating larvae. Dissections for the plots showed the following percentages of infestation: broomcorn millet, 56.8; broomcorn, 32; teosinte, 27; sorghum, 20; German millet, 10.4; buckwheat, 7.5; hemp, 6; and sudan grass, 3.2.

Negative results have been obtained with soybean, Hungarian millet, flax, cotton, sugar beet, emmer, beans, pumpkin, squash, and okra.

A block of mugwort (*Artemisia vulgaris*), an uncultivated host commonly infested in Europe, also gave negative results.

INFESTATIONS IN ORNAMENTALS. Scouting for infestations in ornamentals was confined mostly to nursery stock remote from corn. Under these conditions, 14 species were examined. With the exception of peony, in which one larva was found, all these species were free from infestation.

ORNAMENTALS EXAMINED FOR EUROPEAN CORN BORER INFESTATION

Gladiolus	*Gladiolus* sp.
Aztec dahlia	*Dahlia pinnata* Cav.
Heliopsis	*Heliopsis* spp.
Peony	*Paeonia officinalis* L.
Black-eyed-susan	*Rudbeckia hirta* L.
Goldenglow, a horticultural variety of	*Rudbeckia laciniata* L.
Mulberry chrysanthemum	*Chrysanthemum morifolium* Ram.
Swamp aster	*Aster puniceus* L.
Garden phlox	*Phlox paniculata* L.
Zinnia	*Zinnia elegans* Jacq.
Italian bugloss	*Anchusa italica* Retz.
Yucca	*Yucca* spp.
Oxeye butterflybush, a horticultural variety of	*Buddleia davidi* Franch.
Eulalia	*Miscanthus sinensis* Anders.

Alongside of corn, 6 larvae were taken from 65 dahlia plants, and 1 larva from 100 gladioli.

As yet no complaints of European corn borer infestations have been received from growers of ornamentals in southeastern Michigan.

FORCED INFESTATIONS IN SOME COMMON WEEDS AND CROP PLANTS. A. *Individual Cage Experiments.* These experiments were begun in 1927 with three objects in view: (1) to determine the rate of larval establishment and survival, (2) to ascertain the longevity of the species on the respective hosts in the absence of corn and whether or not there is any degeneration, (3) to see whether there is any change in the life cycle.

Most of the plants selected for these investigations may be found growing in or near cornfields and have stems large enough to support the full grown larva of the European corn borer.

The following species were represented from 1927 to 1930.

Amaranthus retroflexus L.	(pigweed) '27, '28, '29
Polygonum persicaria L.	(ladysthumb) '27, '28, '29
Xanthium commune Britton	(cocklebur) '27, '28, '29
Ambrosia trifida L.	(big ragweed) '27, '28, '29
Ambrosia elatior L.	(ragweed) '28, '29
Abutilon theophrasti Medic.	(velvetleaf) '28, '29
Arctium minus Bernh.	(burdock) '27, '28, '29
Rumex crispus L.	(curlydock) '27, '28

Chenopodium album L. ..... (lambsquarters) '27, '28, '29
Aster paniculatus Lam. ..... (tall white aster) '28, '29
Aster puniceus L. ..... (swamp aster) '28, '29
Verbascum thapsus L. ..... (flannel mullen) '27
Soja max L. ..... (soybean) '27, '28, '29
Fagopyrum esculentum Moench. ..... (buckwheat) '27, '28, '29
Cannabis sativa L. ..... (hemp) '28, 29
Panicum miliaceum L. ..... (broomcorn millet) '27, '28, '29
Cirsium arvense (L.) Scop. ..... (Canada thistle) '29
Bidens frondosa L. ..... (beggarticks) '29
Artemisia vulgaris L. ..... (mugwort) '29

METHODS. The plants were arranged in small blocks, either by planting the seeds or by transplanting, and were enclosed in cages of wooden structure, 3 feet square and 3 feet high, covered with 18-mesh copper cloth. To accommodate the taller plants, cages 3 feet square and 6 feet high were used. The cages were put over the plants shortly before moth emergence in order to give the plants the longest possible period for normal development.

The project was begun in 1927 by inserting male and female moths into the cages, as it was intended that the insect spend its life cycle under as nearly natural conditions as possible. This procedure proved unsatisfactory, as the moths deposited eggs promiscuously, mostly on the wooden structure of the cages. The method was therefore supplemented by the introduction of newly hatched larvae obtained from eggs deposited in oviposition cages in the laboratory. The young larvae were transferred to the plants by means of a moist camel's-hair brush. Although this method of artificial infestation was more satisfactory than the introduction of moths, the larval establishment on the plants seemed quite low, probably because of handling and lack of ideal shelter and food immediately after hatching. To obviate this difficulty the cages were stocked with eggs from the laboratory and this procedure was continued throughout 1928 and 1929. The eggs were secured from moths confined in cylindrical pasteboard cans which had sheets of paper placed around the inside wall. The paper sheets bearing the egg clusters were removed from the cans and the eggs kept in a moist place until shortly before hatching. The egg clusters were left on small strips of paper which were clamped to the leaves of the plants in the late afternoon or evening.

In 1927 it was impossible to determine accurately the number of eggs each cage received, as the moths originally introduced oviposited on some of the plants.

The cages remained over the plants throughout the winter with the tops removed and screen of one-half inch mesh put in their place to prevent birds and other predators from attacking the larvae. The sur-

viving larvae were removed from the plants to salve boxes in the forepart of April and were retained in an outdoor insectary for pupation and emergence.

To accommodate more plants, some of the cages were increased in size in both 1928 and 1929. In 1928 cages 4 feet square and 6 feet high were used to cover cocklebur, ladysthumb, pigweed, and big ragweed. In 1929 three blocks of cocklebur and one of ladysthumb were covered with cages 4 feet wide, 6 feet long, and 6 feet high.

Extent of Establishment and Survival of the European Corn Borer on Various Weeds and Crop Plants under Cage Conditions.

Table 1. Summary Showing the Percentage Survival of the European Corn Borer in Various Weeds and Crop Plants

Species	1928 Generation	1928 Number of eggs or newly-hatched larvae introduced	1928 Percentage survival in spring 1929	1929 Generation	1929 Number of eggs or newly-hatched larvae introduced	1929 Percentage survival in spring 1930
Ladysthumb	first	546	0.54	first	808	4.7
Ladysthumb	second	220	no survival	——	——	——
Cocklebur	first	353	6.79	first	1,000	10.5
Cocklebur	second	298	10.74	second	397	3.53
Cocklebur	——	——	——	third	1,225	3.59
Big Ragweed	first	367	.27	first	780	5.38
Big Ragweed	second	313	.64	——	——	——
Ragweed	first	225	5.33	——	——	——
Ragweed	——	——	——	second	524	1.91
Broomcorn millet	first	417	.74	——	——	——
Broomcorn millet	——	——	——	second	317	1 89
Pigweed	first	396	.25	first	496	.2
Burdock	"	475	.21	"	148	no survival
Hemp	"	825	no survival	"	512	2.92
Buckwheat	"	643	"	"	420	.48
Swamp aster	"	656	"	"	536	no survival
Tall white aster	"	746	"	"	505	"
Velvetleaf	"	449	"	"	290	"
Lambsquarters	"	621	"	"	415	"
Soybean	"	822	"	"	691	"
Curlydock	"	156	"	——	——	——
Mugwort	——	——	——	first	430	1.63
Beggarticks	——	——	——	"	225	1.96
Canada thistle	——	——	——	"	556	no survival

Polygonum persicaria (Ladysthumb)

Polygonum persicaria, an annual weed common in cornfields, is frequently infested with the European corn borer through larval migration from corn plants. The plant has a cylindrical leaf sheath surrounding

the stem at the node which serves as an ideal place for young larvae to become established. The young larvae feed slightly on the leaves and tender shoots but usually burrow into the nodes and through the pith of the plant.

In 1927, larvae, numbering 18, became full grown and passed the winter in excellent condition. Pupation and emergence were normal and corresponded with those events in the field. A total of 220 eggs were obtained from the moths and were introduced on 50 plants. Shortly after the egg introduction was made, the plants became wilted and dried up as a result of aphid and measuring-worm injury which prevented larval establishment.

In 1929 a new strain was begun on *P. persicaria.* A total of 808 eggs were introduced on 45 plants and 38 larvae were recovered the following spring. All the larvae were normal and in good condition.

Xanthium commune (Cocklebur)

Xanthium commune, commonly known as cocklebur or clotbur, is a coarse pithy annual with branching stems. When present in infested cornfields it is one of the shelter plants most commonly inhabited by the European corn borer in the western area. In eastern New England, where a second generation occurs, it has been found to be the most heavily infested wild host (*1 p. 1*). It tolerates a heavy infestation with only slight wilting. The feeding of the young larvae is confined mainly to the tender tips and pith of the stem and branches.

Eleven larvae were reared on 15 plants in 1927 and passed the winter of 1928 in excellent condition. Pupation and emergence were normal and eggs numbering a total of 298 were obtained from the moths. Of these, 207 were introduced into the cage as eggs and 91 as newly-hatched larvae. A total of 32 larvae, or 10.74 per cent of the eggs, developed into full-grown larvae. The average size of these larvae was smaller than is the case with larvae that pass their life cycle on corn. In another cage of cocklebur, maintained as a check, there were introduced 353 eggs from moths emerged from corn. Of these, 24 larvae, or 6.80 per cent, reached maturity.

In 1929, there were three strains of *P. nubilalis* represented on cocklebur, a check or first generation freshly started on cocklebur, a second generation whose parentage was started on cocklebur in 1928, and the third generation on cocklebur, the parentage of which dated back to 1927. The survival from egg to mature larva for the respective strains was 10.5 per cent for the first generation, 3.53 per cent for the second generation, and 3.59 per cent for the third generation. From external appear-

ances the larvae of the three generations were normal. Pupation and emergence compared favorably with those events as they occurred in the field.

Ambrosia trifida (Big Ragweed)

Ambrosia trifida, a weed common in waste places, is a coarse hairy plant with a compound leaf and stout petioles. In 1927, three larvae were reared on this species. All three specimens pupated and emerged and from one of these, a female, 313 eggs were obtained. From these eggs 2 larvae survived the winter of 1928, although 1 of these specimens died before pupating.

In 1929, a parent strain was again started on this plant. The larval survival of 42, or 5.38 per cent of 780 eggs, was much higher than in either 1927 or 1928 and ranked favorably with the larval survival observed on cocklebur.

Amaranthus retroflexus (Pigweed)

Amaranthus retroflexus is one of the most common weeds found in cornfields. In fields heavily infested by the European corn borer many plants of this pigweed become hosts to the migrating larvae. The larvae usually burrow through the pith of the plants, entering at the buds or petioles.

In 1927, two larvae matured on pigweed, both of which died before pupation. In 1928, one larva matured from a total of 396 eggs. In 1929, one larva matured from 496 eggs.

Ambrosia elatior (Ragweed)

Amborsia elatior is probably the most common weed in cornfields in the Middle West and often serves as a host to migrating larvae. The larvae enter at the top of the stem, killing the bud, and causing the side branches to grow profusely.

Forced infestations in ragweed were begun in 1928. From a total of 225 eggs, 12 larvae matured on this plant. The progeny of this generation were continued on ragweed in 1929, a total of 10 larvae maturing from 524 eggs.

Panicum miliaceum (Broomcorn Millet)

Panicum miliaceum, a millet grown for feed (often called "hog-millet"), is reported as one of the most common hosts of the European corn borer in Poland and Russia.

In 1928, a total of 417 eggs were introduced on broomcorn millet, from which 3 larvae matured. All 3 larvae pupated and emerged normally for the 1929 continuation. Eggs totalling 317 were laid by 1 female moth, from which 6 larvae matured.

Arctium minus (Burdock)

Arctium minus, a large-petioled broad-leaved biennial plant growing in uncultivated ground, occasionally receives an infestation in New England (*1, p. 61*). In 1927, eggs and newly-hatched larvae were introduced but no larvae matured. There was slight feeding on the leaves with a few short tunnels in the petioles, while in 1928 larval feeding was confined mainly to the branches bearing the seeds.

In 1928, a total of 475 eggs were introduced, from which one mature larva was recovered in the spring of 1929. This larva was undersized and died before pupation. In 1929 there were no survivals out of a total of 148 eggs.

Cannabis sativa (Hemp)

Hemp, a rank-growing fiber plant, proved to be a fair host in 1929, when a total of 15 mature larvae were recovered from 512 eggs, whereas in 1928 no survivals were obtained from 825 eggs.

Fagopyrum esculentum (Buckwheat)

Buckwheat, a summer crop belonging to the smartweed group, was artificially infested with eggs and newly-hatched larvae in 1927 and 1928. The young larvae tunnelled slightly in the succulent portions of the stems but perished before maturity. In 1929, however, out of a total of 420 eggs 2 larvae were recovered.

Miscellaneous Plants

Soybean and lambsquarters (*C. album*) were included in the forced-infestation project, from 1927 to 1928, with negative results.

Swamp Aster (*A. puniceus*), tall white aster (*A. paniculatus*), and velvetleaf (*A. theophrasti*) gave negative results in 1928 and 1929.

Mugwort (*A. vulgaris*), beggarticks (*B. frondosa*), and Canada thistle (*C. arvense*) received forced infestations in 1929 only. On mugwort 430 eggs resulted in a survival of 7 mature larvae. In beggarticks 5 larvae survived out of a total of 225 eggs, while no survival was obtained in Canada thistle out of 556 eggs.

No larval establishment was obtained with flannel mullen (*V. thapsus*) which was tested in 1927. Curlydock (*R. crispus*) was given two trials, in 1927 and 1928, with negative results.

B. *Parasite-Conservation Cage.* In the parasite-conservation cages, which are stocked each autumn, for parasite-recovery purposes, with the infested corn fodder grown on 10 acres, large numbers of moths emerge to deposit their cage on whatever material is at hand. Under cage conditions the moths have a peculiar habit of laying many of their eggs on the wooden structure of the cage. However, many eggs are also deposited on the green plant material present in the cage.

Under these conditions egg and larval infestations have been found on the following species:

Rippleseed plantain and buckhorn plantain	(*Plantago major* L. and *P. lanceolata* L.).
Dandelion	(*Taraxacum officinale* Weber)
Ladysthumb	(*Polygonum persicaria* L.)
Canada thistle	(*Cirsium arvense* (L.) Scop.)
Teasel	(*Dipsacus sylvestris* Mill.)
Lambsquarters	(*Chenopodium album* L.)
Beggarticks	(*Bidens frondosa* L.)
Cocklebur	(*Xanthium commune* Britton.)
Burdock	(*Arctium minus* Bernh.)
Ragweed and big ragweed	(*Ambrosia elatior* L. and *A. trifida* L.)
Curlydock	(*Rumex crispus* L.)
Velvetleaf	(*Abutilon theophrasti* Medic.)
Pigweed	(*Amaranthus retroflexus* L.)
Whitetop	(*Erigeron canadensis* L.)
Barnyard grass	(*Echinochloa crusgalli* L.)

Oviposition was most abundant on ladysthumb (*P. persicaria*), beggarticks (*B. frondosa*), big ragweed (*A. trifida*), and rippleseed plantain (*P. major*), in the order named.

Egg infestations have also been found on milkweed (*Asclepias syriaca*) and prickly lettuce (*Lactuca scariola*). However, no larval feeding has been noted on these plants.

SUMMARY. In the more heavily infested areas of Michigan, the European corn borer is occasionally found in the common weeds growing among corn. Judging from data available at the present time, it is believed that these infestations are brought about by larval migration from corn.

In experimental plots contiguous to corn, liberal infestations have occurred in broomcorn millet, broomcorn, sorghum, Sudan grass, and Hungarian millet when these plants were at a stage of development attractive to the moths. The fact that the insect has a single generation annually and emerges at a period when corn is abundantly present at a stage of development very attractive to the ovipositing moths has no doubt been an important factor in keeping the pest closely associated with its primary host.

In the absence of corn in cages, the borer has consistently established

itself on a variety of plants, proving that the insect can live on crop plants other than corn and in common weeds in the western area.

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SOME STUDIES ON THE PLANTING RATE OF CORN IN RELATION TO OVIPOSITION, POPULATION AND INJURY BY THE EUROPEAN CORN BORER

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ABSTRACT

This report relates to some of the progress made during two seasons of study pertaining to the planting rate of corn in relation to corn borer (*Pyrausta nubilalis* Hubn.) behavior with special reference to oviposition, population, survival and injury. Egg distribution in the different rates of planting did not appear to be directly proportional to either unit area or plant units but was more dependent on the former. Populations were greater in the thinner plantings and larval survival increased with the thickness of stand. The injury also seemed greater in the sparser plantings.

Hill plantings consisting of 1, 2, 3, 4, 5 and 6 plants per hill were studied in 1930 and plantings consisting of 1, 2, 3, 4 and 5 plants per hill were observed during 1931. Row plantings having the plants placed at intervals of approximately 6, 12, 18, 24, 30 and 36 inches were used in 1930 and the first five of these rates were used again in 1931. The variety used was Clement's White Cap Yellow Dent. It was planted on May 7 in 1930 and on May 5 in 1931. The hills and rows were spaced 42 inches apart. In addition to these plots, a check area in which hills having varying numbers of plants ranging from 1 to 5 placed at random in a single square of 120 hills, was observed.

Due to the higher egg deposition and borer loads encountered in 1931, observations included in this paper are confined to these experiments, except where reference is made to the previous observations. Although the plantings are referred to by their anticipated rate of stand, slight variations were encountered in all the planting rates used due to occasional misses in the hills or rows. All of the rates discussed contained slightly fewer plants than the rate by which they are designated would indicate.

COMPARATIVE OVIPOSITION observations were made at three day inter-

vals on a unit area basis. Thus, the two center rows of each plot with the exception of a two-row barrier at each end of the plots in the hill plantings and an equal area in the same relative position in the plots of the row plantings were observed for eggs. Therefore, 16 hills were observed in each plot of the hill plantings and such plants as occurred within an equal space in the plots which were planted in rows. The masses were left on the plants and were marked by means of holes punched at the sides of the masses next to the margins of the leaves. The number of eggs was determined by multiplying the number of egg clusters by 17.62, this figure representing the average number of eggs per mass as determined by counts of masses at various intervals throughout the oviposition period.

In the several rates of planting under discussion, the corn did not appear to receive eggs directly on the basis of the unit area available for oviposition or on the basis of the number of available plant units. In both hill and row plantings (Table 1) more eggs were received by the thicker plantings than by the thinner ones when considered from the point of view of unit area. When considered on the basis of plant units, the thinner plantings received more eggs than the thicker ones. That the distribution of eggs was more dependent on the unit area involved than on the number of plant units is evident, however, as the variations in the number of eggs received by thick and thin plantings was much greater when considered from the point of view of plant units than when considered from the point of view of unit area.

TABLE 1. EGG DISTRIBUTION IN HILL AND ROW PLANTINGS CONSIDERED FROM THE POINT OF VIEW OF PLANT UNITS AND UNIT AREA

Hills or rows	No. of plants per hill or distance apart in inches in the row	No. of eggs received per acre	No. of eggs received per 100 plants
Hills	1	146,914	4,379
Hills	2	171,236	2,491
Hills	3	158,259	1,542
Hills	4	198,122	1,444
Hills	5	192,054	1,179
Rows	30	132,063	2,438
Rows	24	162,551	2,422
Rows	18	164,230	1,852
Rows	12	166,066	1,402
Rows	6	195,508	1,088

A consideration of the data relative to egg distribution in the check area where the number of plants per hill varied from 1 to 5 and these hills placed at random in a single plot, showed a relationship between plot and area units and egg distribution similar to that existing in the

experiment proper. More eggs were received by the hills having the greater number of plants but the plants which occurred in the smaller hills received the most eggs per individual. Thus, the 1 plant hills received 29.95 eggs per hill, the 2 plant hills 36.20 eggs, the 3 plant hills 38.76 eggs, the 4 plant hills 44.60 eggs and the 5 plant hills received 49.90 eggs per hill. On the basis of plant units, the plants in 1 plant hills received 29.95 eggs per plant, the 2 plant hills 18.10 eggs per plant, the 3 plant hills 12.92 eggs, the 4 plant hills 11.15 and the 5 plant hills 9.98 eggs per plant. It seemed much less evident in this check area that egg distribution was governed by unit area than in the experiment proper. In this check the high and low rates of oviposition in the two extremes of thickness of stand varied further from an average of the 5 rates studied than in the plantings in which entire plots were planted at a uniform thickness.

A comparison between the heights of the various planting rates during the egg laying period and the number of eggs received by each would seem to indicate that height was of some consequence in determining the variations that occur in the general trend toward greater numbers of eggs per plot in the thicker plantings but would not account for the proportional increase of eggs which occurred with each increased thickness of stand. The average heights of the plots having 1, 2, 3, 4 and 5 plants per hill during the oviposition period were 48.46, 50.01, 49.86, 51.92 and 51.01 inches while the numbers of eggs per unit area were 2978, 3471, 3208, 4016 and 3893 respectively for each unit area observed. It seems probable in this instance that height may have played a part in producing these variations from what might be considered the normal trend. Only very slight differences occurred in the heights of the row plantings.

Comparative studies of the relative leaf area and the number of eggs deposited on the six rates used in 1930, would seem to indicate that this factor might be of more importance in relation to egg laying than either height, plant units or unit area, since the leaf area per unit space increased more proportionately to the egg deposition than did the other factors.

Population and Survival. Infestations and populations were taken on the same plants which were examined for eggs so that direct comparisons could be made between oviposition and population. Due to the fact that practically all of the plants were infested in all of the plots, infestation records could not be used as a basis of comparison between planting rates.

The populations of the various plantings were comparatively higher in the thicker than in the thinner stands when viewed on unit area basis

(Table 2). On the basis of plant units relatively higher populations occurred in the thinner stands. The higher populations per unit area were due to the greater number of eggs which were deposited on the thicker corn and also to the higher rate of larval survival in these plots. The survival factor seemed to be the most important one. This relatively higher survival as discussed by Neiswander, Polivka and Huber (1) could be directly correlated with the relative leaf surface of the area units under discussion and occurred in spite of the unfavorable position of the thicker stands of corn due to their slightly retarded development.

TABLE 2. RELATIVE POPULATION AND SURVIVAL OF THE TEN PLANTING RATES USED IN 1931

Hills or rows	No. of plants per hill or distance apart in inches in the row	No. of larvae per unit area	No. of larvae per 100 plants	Per cent survival
Hills.....	1	338	426	10.98
Hills.....	2	514	386	14.15
Hills.....	3	536	269	17.47
Hills.....	4	650	258	18.43
Hills.....	5	682	246	20.67
Rows.....	6	744	186	20.69
Rows.....	12	578	253	20.46
Rows.....	18	624	364	18.19
Rows.....	24	482	380	18.10
Rows.....	30	448	387	12.97

Larval survival in the check area correlated in general trend with that of the other plots. Populations were taken, however, in early August in the check and not until late October in the remainder of the experiment so that the survival figures are considerably higher for each given rate in the check area. The populations per hill unit were as follows: 1 plant hills 4.95 borers, 2 plant hills 8.11 borers, 3 plant hills 13.12 borers, 4 plant hills 15.60 borers and 5 plant hills contained an average of 17.05 borers per hill. The number of larvae per plant varied between the low population of 3.41 borers per plant in the 5 plant hills and 4.95 borers per plant taken in the 1 plant hills, while the intermediate rates of 2, 3 and 4 plants per hill had proportional borer loads. The survival rates in this check area were 16.52 per cent in the 1 plant hills and 36.42 per cent in the 5 plant hills with the intermediate stands having corresponding survival rates. As shown by these figures, the difference in the populations per unit area between the thick and the thin stands was greater than in the experiment where the several planting rates were arranged separately in plots. Thus, 5 plant hills contained approximately three times as many borers as the 1 plant hills while in the experiment proper the 5 plant hills contained only twice as many as the one plant hills.

Three of the six replications of each planting rate in both hills and rows were artificially infested with eggs, the object being to build the

population up to a level where serious injury would occur. Egg masses which were produced in the laboratory on wax paper and incubated almost to the point of hatching were deposited in the unopened buds of the plants on a unit area basis.

Assuming that the survival rate of the natural eggs in the artificially infested plots was the same as in the plots which were naturally infested only, figures relative to the survival resulting from the artificially placed eggs were determined. These survival rates varied between 6.19 per cent in the 1 plant hills and 14.30 per cent in the 5 plant hills. In the row plantings in which the plants were placed at intervals of 30 inches the survival was 6.10 per cent and 19.37 per cent in the thicker plantings in which the plants were placed 6 inches apart. The survival rates in the stands intermediate between the extremes just quoted had proportional survivals. The figures representing these survivals from artificially placed eggs were consistently lower than those resulting from naturally deposited eggs upon plots planted at equal rates.

INJURY AND YIELD. The comparative injury to the corn as indicated by the presence of broken stalks was well marked. It seemed that under the existing variable populations occurring in the planting rates studied that the injury as expressed in this manner decreased as the planting rate was increased. In a comparison of the occurrence of this form of injury, the number of units affected in this way seemed to be greater in the thicker plantings but the percenatge of affected plants was greater in the thinner plantings. The number of breaks per 100 plants in the naturally infested plots including those occurring both above and below the ears was 88.57 in the 1 plant per hill plantings and 52.14 in the plantings having 5 plants per hill while row plantings exhibited an equivalent condition. Little variation was noticeable in the number of tassels infested and broken in the thick and thin plantings as practically 100 per cent infestation and breakage occurred in all the plots regardless of the thickness of stand. Ear infestation, ear shank infestation and breakage and the presence of undeveloped ears due directly to injury to other portions of the plants, showed less variation in the different rates of stand than did stalk breakage. Thus, the percentage of infested ears was 18.19 in the 1 plant per hill stands and 15.79 in the 5 plant plots while the row plantings showed equivalent degrees of injury in this respect. The amount of injury, therefore, as expressed in the manners mentioned above, seemed to occur inversely to the thickness of stand when considered on the basis of plant units. Contrary to the trend of these other types of injury, the percentage of barren plants increased with the thickness of stand.

Yield, as expressed by the number of bushels of shelled corn per acre, allowing 15.5 per cent moisture, was greater in the row plantings having the plants placed at 12-inch intervals than in any of the other rates studied (Table 3). This was true of both the naturally infested plots and also of the artificially infested plots where populations were slightly more than double those of the naturally infested plantings.

TABLE 3. YIELD OF CORN IN VARIOUS PLANTING RATES IN 1931

Hills or rows	No. of plants per hill or distance of plants apart in in.	Actual number of plants per acre	No. of borers per 100 plants	No. of bushels of shelled corn per acre
Hills.....	1	3,355	426	24.84
Hills.....	2	6,857	386	40.57
Hills.....	3	10,261	269	45.50
Hills.....	4	13,715	258	49.75
Hills.....	5	16,280	246	47.46
Rows.....	30	5,328	387	38.55
Rows.....	24	6,543	380	42.91
Rows.....	18	8,732	364	52.25
Rows.....	12	11,845	253	56.64
Rows.....	6	17,957	186	54.41

It is not assumed, however, that this is the best rate to plant under corn borer conditions but may tend to show the superiority of somewhat thicker planting than is customary under present conditions or to emphasize the importance of having good stands of corn as they particularly effect yield under corn borer conditions. Other intervals of planting not included in these studies may have produced better yields where this variety and planting date were used, or similarly, other varieties, planting dates or levels of fertilization might have produced different results with the planting rates and variety used.

DISCUSSION. Studies relative to egg distribution in 6 rates of planting in rows and 6 rates in hills seemed to indicate that the eggs were not deposited on the plants directly on the basis of plant or unit area but that such distribution was influenced more by unit area than plant unit. The survival of the insect from the egg to the full grown borer stage seemed to be proportional to the thickness of stand and to correlate directly with the leaf area occurring per unit area. Injury, as expressed in terms of infestation and breakage in various parts of the plants, seemed to be inversely proportional to the thickness of stand, the thinner plantings containing the greatest borer load per plant unit and also being the most severely injured. Although these observations were made only on corn of one variety, planting date and condition of soil and therefore can show no specific best planting rate for corn under all conditions, it seems probable that somewhat thicker stands than are ordinarily grown

might be of advantage and that uniform and full stands of corn may be more important in borer infested than in borer free areas.

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LIFE HISTORY OF *THRIPS TABACI* L. ON *EMILIA SAGITTATA* AND ITS HOST PLANT RANGE IN HAWAII[1]

By K. SAKIMURA, *Assistant Entomologist*[2]

ABSTRACT

Thrips tabaci L., the transmitter of pineapple yellow spot disease, is an introduced species in Hawaii but is now well established throughout the Islands. It has been collected from 66 different plants. The life history of the species on *Emilia sagittata*, one of the most important wild hosts of both insect and virus, has been studied. On this host plant chlorotic malformation of the leaves results from the insect's feeding. Parthenogenetic reproduction occurs normally under Hawaiian conditions and the biotic potential of the insect is extremely high.

Thrips tabaci Lind., the common onion thrips has recently been reported in Hawaii as the transmitter of pineapple yellow spot, a virus disease of the pineapple plant. The virus is present in a number of wild weed hosts but *Emilia sagittata* is probably the most common of these (4, 5). This weed is also one of the most preferred host plants of *Thrips tabaci* so a study has been made of the life history of the insect on this species.

HISTORY OF *Thrips tabaci* L., IN HAWAII. The first systematic study of Hawaiian Thysanoptera was done by R. S. Bagnall (1) who examined the materials which were collected, probably up to 1901 or 1902, by R. C. L. Perkins. *Thrips tabaci*, however, was not listed by Bagnall. D. T. Fullaway (3) first reported this species from crucifers in Hawaii during 1914 and later Moulton (8) recorded the species collected by O. H. Swezey on Oahu and Maui during 1927.

The species is not indigenous to Hawaii and definite evidence of its continued importation to the Islands was obtained in October 1930 when onion sets were received at the laboratory from a grower at Corvallis,

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[2]Acknowledgments are due Dr. Walter Carter, under whose direction the present studies were conducted, for many valuable criticisms and suggestions, and Mrs. H. M. Hoshino, who determined a part of the plant specimens.

Oregon. These onion sets were heavily infested with *Thrips tabaci* which were hiding in the spaces between the fresh and dried skin at and around the tips of the bulbs. Of a sample of 50 onion sets examined, 14 were found infested containing 5 adults, 3 1st instar larvae, 2 2nd instar larvae, 3 pupae as well as 7 dead adults. Since these sets had been harvested on July 1st, 1930, the thrips had evidently continued to reproduce in the bulbs. The species is now distributed throughout the Hawaiian Islands with a large number of wild and cultivated host plants.

HOST PLANTS. Extensive collections have been made only on the Island of Oahu but incidental collections have been made on the Islands of Hawaii, Kauai, Lanai, Maui and Molokai by Dr. Walter Carter and the data from these collections are included in the accompanying list.

The list of host plants given below in Table 1, will no doubt be materially lengthened as time goes on and more detailed attention can be given to the fauna of the other Islands. A large number of other species, many of them new, have been found while collecting *Thrips tabaci*. *Taeniothrips hawaiiensis* Morgan and *Haplothrips gowdeyi* Franklin are very common species and usually associated with *Thrips tabaci* on various host plants, although the former two are essentially flower feeders while the latter feeds apparently on any aerial portion of the plant.

TABLE 1. LIST OF THE HOST PLANTS OF *Thrips tabaci* L. IN HAWAII

Adults only were taken from plants marked thus: *

Family *Gramineae*
- Paspalum conjugatum Gergius*
- Cenchrus sp.*
- Eleusine indica (L.) Gaertner
- Syntherisma chinensis Nees
- Syntherisma sanguinalis (L.) Dulac

Family *Bromeliaceae*
- Ananas sativus Schultes (pineapple)[5]

Family *Liliaceae*
- Allium sp. (onion) [1] [2] [3] [4]
- Yucca sp.

Family *Amaranthaceae*
- Amaranthus albus L.
- Amaranthus retroflexus[2]

Family *Nyctaginaceae*
- Mirabilis jalapa L.*

Family *Phytolaccaceae*
- Phytolacca acinosa Roxburg

Family *Portulacaceae*
- Portulaca oleracea L.

Family *Caryophyllaceae*
- Dianthus sp. (carnation)

Family *Cruciferae*
- Brassica nigra Koch.
- Raphanus sativus L.
- Raphanus sativus longipinnatus Bailey (white radish)
- Senebiera didyma Persoon

Family *Leguminosae*
- Acacia farnesiana (L.) Willd.*
- Cajanus cajan (L.) Millsp. (pigeon pea)

[1]Specimens also examined from Hawaii
[2]Specimens also examined from Kauai
[3]Specimens also examined from Lanai
[4]Specimens also examined from Maui
[5]Specimens also examined from Molokai

Cassia mimosoides L.*
Cassia occidentalis L.
Cassia tora L.*
Crotalaria juncea L.
Crotalaria saltiana Andr.
Crotalaria spectabilis Roth.
Glycine max Merr. (soy bean)* [1]
Leucaena glauca (L.) Bentham*
Lupinus sp.
Mimosa pudica L.
Medicago sativa L. (alfalfa)
Phaseolus lathyroides L.*
Pisum sativum L. (edible podded pea)
Prosopis juliflora (Sw.) DC.*
Vigna sinensis (L.) Endl. (cowpea)

Family *Oxalidaceae*
Oxalis martiana Zuccarini

Family *Euphorbiaceae*
Euphorbia hirta L.

Family *Malvaceae*
Malva sp.

Family *Sterculiaceae*
Waltheria americana L.

Family *Lythraceae*
Cuphea hyssopifolia H. B. K. [4]

Family *Araliaceae*
Nothopanax guilfoylei Merr. (panax)

Family *Umbelliferae*
Daucus carota L. (carrot)
Hydrocotyle asiatica L.*

Family *Convolvulaceae*
Ipomoea tuberculata Roemer* [3]

Family *Boraginaceae*
Bothriospermum tenellum F. & M.

Family *Verbenaceae*
Lantana camara L.
Stachytarpheta dichotoma Vahl
Verbena bonariensis L.

Family *Labiatae*
Stachys arvensis L.*

Family *Solanaceae*
Nicandra physalodes Persoon
Solanum nodiflorum Von Jacquin

Family *Rubiaceae*
Richardsonia scabra St. Hilaire

Family *Cucurbitaceae*
Cucumis dipsaceus Ehrhart*

Family *Compositae*
Acanthospermum xanthoides De Candolle
Ageratum conyzoides L.[2]
Ambrosia artemisiaefolia L.*
Bidens pilosa L.[2]
Chrysanthemum sp.
Emilia sagittata (Vahl) DC. [2 3]
Erigeron canadensis L. [2 3]
Gnaphalium luteo-album L.*
Pluchea indica Cassini
Senecio hieracifolia L.
Sonchus oleraceus L.
Tithonia rotundiflora (Miller) Blake
Vernonia cinerea Less.

[1]Specimens also examined from Kauai
[2]Specimens also examined from Lanai
[4]Specimens also examined from Maui

Table 1 indicates that 66 wild and cultivated plants belonging to 25 different families are host plants of *Thrips tabaci* in the Hawaiian Islands with the *Compositae* and *Leguminosae* as the predominating families. Onion is one of the most preferred host plants as is the case elsewhere and wherever onions grow in Hawaii this species is present. Pineapple plants are apparently accidental hosts though the insect freely feeds and breeds on their influorescences.

Feeding Injuries to *Emilia sagittata*. In addition to the transmittal of the virus of yellow spot, *Thrips tabaci* causes mechanical injuries to the plant. The feeding habits of this species on cotton leaves were fully described by Wardle and Simpson (11). In the case of *sagittata*, the so-called feeding scar, the silvery whitish sunken area is the direct result

of their attack. Young terminal leaves frequently show malformations when heavily attacked, with crinkly surfaces, sunken and raised thin areas, marginal erosion, margin curling inwardly and a chlorotic yellowish appearance with grayish color along all the large veins. These injuries are produced by both viruliferous and non-viruliferous insects. The malformed small leaves appear in bunchy form on terminals. Young buds are easily killed as soon as they come out and plant growth is much retarded. These last-named injuries are only seen when thrips are confined on plants in cages and are not found in the field even in the districts where very high thrips populations are encountered. This malformation of young leaves is apparently very similar to that caused by the same insect on seedling cotton as reported from South Carolina (2).

In addition to feeding on leaves they also freely feed within flowers, attacking the tender portion. It is also probable that they cause sterility of seeds as in the case of the same insect on onion in California (9). This point has not been shown as yet in connection with *Emilia sagittata*. The amount of food consumed by the insects on different host plants is being studied and the results will be reported in a separate paper.

PARTHENOGENETIC REPRODUCTION. Eighty-five progenies from unmated females which were studied in the course of the life history work during the winter months, were found to be all females. In addition, over 5000 specimens from various sources were examined under the microscope and these were all females except 5. It seems safe to assume that the male of this species is extremely scarce in Hawaii and that parthenogenetic reproduction is a normal condition. These data agree fairly well with the cases in Michigan (10) and Manchester (6). In this connection it might be mentioned that the sample of thrips that came from the onion sets imported from Oregon contained 25% males. This colony was bred on onions after its arrival and in March 1931 examination showed that the entire colony was female. Since scarcity of males during the summer and abundance in the fall is a common phenomenon among this group of insects in the temperate zone, it can be presumed that the high percentage of males in the Oregon material was the result of the low temperatures prevailing at the point of origin of the insect, although some observers point out that the species shows only minor differences in sex ratio in summer and winter. Between the date of their arrival in Hawaii in October and the re-examination of the colony in March, the lowest mean monthly temperature was 71°F. occuring in January.

TECHNIQUE EMPLOYED IN LIFE HISTORY STUDIES. The technique

used was a modified form of that used by McGregor and McDonough (7) in studying red spider on violet. A piece of white thick felt ¾ of an inch square with a ⅜ inch diameter hole at the center was used, being fastened to the leaf with two pieces of celluloid and an ordinary stationery clip. The felt was set on the leaf and the insect transferred into the central hole. Both the underside of the leaf, just below the felt and over the felt, were covered with pieces of celluloid, the whole thing clipped together with a paper clip. Insects can be freely transferred to these cages with camel's hair brushes.

With this technique a single thrips can be confined in each cage and examined daily under the microscope. Temperatures in the cages were measured by means of a thermocouple and found to deviate very little from outside temperatures. The formation of dew on either side of the celluloid was not observed.

LIFE HISTORY. Specimens used in these studies originated from two pupae which were collected from *Emilia sagittata* grown under greenhouse conditions. The records are presented in Tables 2 and 3 and in Figure 55.

In Figure 55 the data are summarized in chart form with the addition of a graph of the mean monthly temperatures.

It is interesting to note that even with the narrow range of temperatures encountered, a noticeable lengthening of the time required to complete both the individual stages and the life cycle was observed in the cooler months. Detailed data on the individual instars are not available except in 23 instances which showed an approximately equal developmental time for each of the larval instars. There was no indication of hibernation during the winter months. This is an important consideration in connection with the introduction of parasites into Hawaii for the control of *Thrips tabaci*. *Thripoctenus russelli* Crawford, which is being introduced at the present time into Hawaii from Los Angeles County, California, apparently has a definite hibernation period and in addition has a much longer life cycle, owing to the length of the pupal period, than *tabaci*. It would appear from these data that *russelli* is unlikely to be an effective parasite unless there is a rapid adaptation on its part to Hawaiian climatic conditions.

SUMMARY. *Thrips tabaci* L. is an introduced species in Hawaii and is now established and distributed all over the Islands. Sixty-six species of plants from 25 families are reported to be host plants of the insect. In addition to the silvery appearing feeding scar, chlorotic malformation occurs as a result of heavy feeding on young leaves of *Emilia sagittata*. The insect may reproduce parthenogenetically throughout the season

TABLE 2. DEVELOPMENTAL TIME IN DAYS OF STAGES OF *Thrips tabaci* L. FED ON *Emilia sagittata*. 1930–1931, HONOLULU, HAWAII

Month	Egg				Larva				Prepupa				Pupa				Life Cycle			Monthly mean T. (F.)
	No. of cases	Av.	Max.	Min.	No. of cases	Av.	Max.	Min.	No. of cases	Av.	Max.	Min.	No. of cases	Av.	Max.	Min.	Av.	Max.	Min.	
1930																				
Oct....	101	4.19	6	3	6	7.66	9	6	6	1.50	2	1	5	2.80	5	1	16.15	19	14	76.55
Nov...	68	4.55	6	3	23	9.08	13	6	21	1.66	3	1	24	2.87	4	1	18.16	22	13	74.26
Dec...	143	4.85	7	4	45	9.26	13	6	38	1.55	2	1	34	3.52	5	3	19.18	23	15	72.29
1931																				
Jan....	17	4.82	7	4	11	9.54	12	7	19	1.42	2	1	22	3.53	5	3	19.31	26	17	72.40
All gen.	329	4.53	7	3	85	9.14	13	6	84	1.54	3	1	85	3.30	5	1	18.51	26	13	73.87

TABLE 3. RECORD OF UNMATED FEMALES OF *Thrips tabaci* FED ON *Emilia sagittata* 1930–1931, HONOLULU, HAWAII
(Time shown in days)

Season	Preoviposition period			Oviposition period			Post-oviposition period			Adult life			No. of eggs laid			Daily oviposition			Daily mean T. (F.)
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	
Early Oct.–mid Nov. (1930).....	4.8	7	4	14.0	30	4	2.2	3	1	21.0	35	11	34.4	51	12	2.5	9	0	76.97
Early Dec.–mid Jan. (1931).....	7.0	12	4	26.6	35	22	6.6	11	4	40.3	52	32	42.0	55	31	1.6	6	0	72.10
Late Dec.–late Feb. (1931).....	6.0	14	3	23.7	43	2	3.9	10	1	28.9	51	14	37.5	109	0	1.6	9	0	73.02
All Gen.....	6.1	14	3	22.5	43	2	3.9	11	1	32.4	52	14	37.4	109	0	1.7	9	0	73.30

under Hawaiian conditions. The average length of the life cycle is 18.51 days and of the egg, 1st instar, 2nd instar, pre-pupal and pupal, 4.53, 4.57, 4.57, 1.54 and 3.30 days respectively. The average adult life is

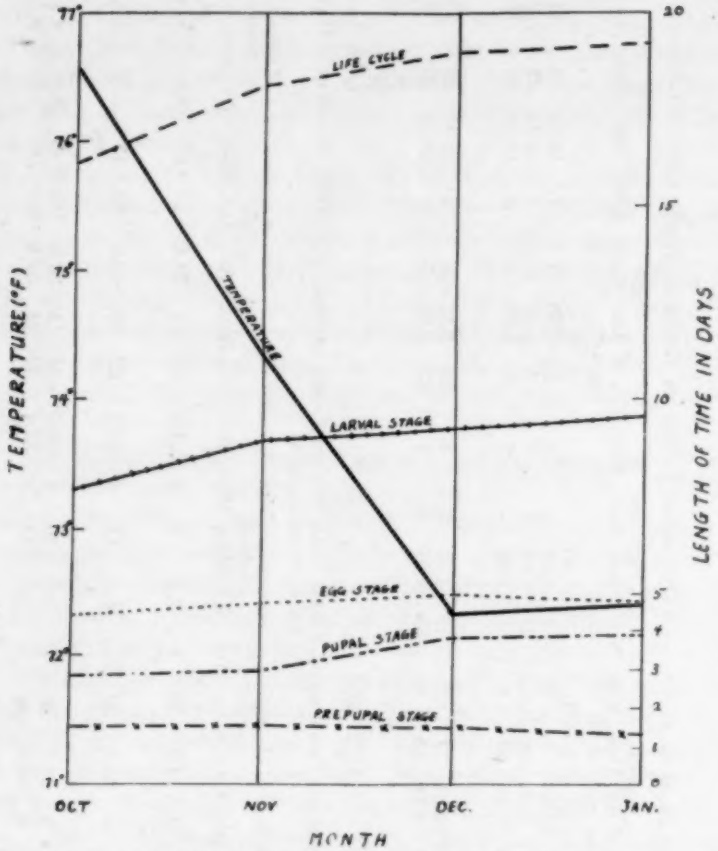

FIG. 55.—Relation between temperature and length of various stages of *Thrips tabaci* feeding on *Emilia sagittata*.

32.4 days and pre-oviposition, oviposition and post-oviposition periods are 6.1, 22.5 and 3.9 days respectively. The average number of eggs laid by an unmated female is 37.4. Under prevailing Hawaiian climatic conditions the biotic potential of this species is extremely high.

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TWO ECONOMIC GREENHOUSE MEALYBUGS OF MISSISSIPPI

The Citrus Mealybug and the Mexican Mealybug

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ABSTRACT

The life histories of the citrus mealybug, *Pseudococcus citri* and the Mexican mealybug, *Phenacoccus gossypii*, are compared under greenhouse conditions. *P. citri* completed 8 life cycles in 365 days, while 381 days were required for *Ph. gossypii* to complete the same number. Mortality, parthenogenetic reproduction, effect on hosts, and recognition characters are discussed.

This paper deals with the life histories of the citrus mealybug, *Pseudococcus citri* (Risso), and the Mexican mealybug, *Phenacoccus gossypii* (T. & Ckll.) under glasshouse conditions, as in Mississippi they are mealybugs of economic importance mainly to nurseries. The chief objects of these experiments over a period of one year were to determine the number of life cycles each species passed through during the year, the length of time between instars, number of eggs laid by the female, the per cent of mortality, etc. The host plant has been coleus as it seemed to be a preferred host for both species. As the experiments were run under glasshouse conditions, an effort was made to keep the temper-

ature somewhat uniform. Yet, at short intervals the temperature has been down to 55°F., during the winter and as high as 95°F. at intervals during some of the summer months, these being possibly the two extremes.

Acknowledgments are due Professor G. F. Ferris for his advice and helpful suggestions. They are also due Mr. Howard Berry, my assistant in the Scale Insect Department of the Mississippi State Plant Board, for the photographs used.

Life History

The experiments with *P. citri* and *Ph. gossypii* were carried on together, and in discussing the life cycles of each it seems best to compare one with the other.

Life Cycle. The first life cycle of *P. citri* was started on May 18, 1930, the last ending on May 25, 1931. Eight life cycles were completed in 365 days. The extra 7 days were lapses of 3 and 4 days in two different cases between two life cycles. In one case the eggs laid the third day after maturity were propagated; in the other the eggs laid the fourth day after maturity were isolated and the progeny carried on. The 8 life cycles varied from 37 to 57 days in length, giving 45.62 days as the average life cycle for the year. During the three summer months of 1930 several experiments with the male scale were carried on, which gave the life cycle from egg to death to be 34 to 47 days in length with an average of 40.83 days. The males during the cocoon stage have a tendency to group together at protected places, as shown by Plate 25, Fig. 5. Plate 25, Fig. 1 shows adult male distinctly with only two waxy protuberances at posterior end.

The first life cycle of *Ph. gossypii* was started on July 26, 1930, the last ending on August 11, 1931. Eight life cycles were completed in 381 days. The life cycles varied from 38 to 57 days in length, the average life cycle for the year being 47.62 days. Several experiments with the males of *Ph. gossypii* run during the summer months of 1930 gave the life cycle from egg to death to be 34 to 46 days in length with an average of 40.62 days. The males have a tendency for isolation during the cocoon stage, as shown in Plate 26, Fig. 5. Plate 26, Fig. 1 shows males to have four waxy protuberances at posterior end.

The length of the different instars of *P. citri* and *Ph. gossypii* can be better shown by the following charts:

P. citri Females

	Days	Average number of days
Length of time for eggs to hatch	3–16	7.12
Hatchings to first molt	9–15	11.37
First molt to second molt	6–13	9.62
Second molt to third molt	4–12	6.87
Third molt to first eggs laid	7–15	10.49
Complete life cycle	37–57	45.62

P. citri Males

	Days	Average Number of days
Length of time for eggs to hatch	3–5	4.26
Hatching to first molt	10–15	12.06
First molt to cotton cocoon*	4–21	10.12
Beginning of cotton cocoon to 2nd molt	1–3	2.12
Second molt to third molt	2–3	2.63
Third molt to fourth molt	3–5	4.28
Fourth molt to death	3–7	4.76
Complete life cycle	34–47	40.83

*The male produces a cottony cocoon between the first and second molt, usually two days before. Within this cocoon the male molts for the second, third, and fourth time, emerging after the fourth molt as the adult winged male.

Ph. gossypii Females

	Days	Average Number of days
Length of time for eggs to hatch	5–16	11.57
Hatching to first molt	6–15	10.71
First molt to second molt	7–10	8.85
Second molt to third molt	4–14	6.57
Third molt to first eggs to be laid	5–12	7.71
Complete life cycle	38–57	47.62

Ph. gossypii Males

	Days	Average number of days
Length of time for eggs to hatch	5–9	6.23
Hatching to first molt	7–12	9.15
First molt to cotton cocoon	5–20	9.30
Beginning of cotton cocoon to second molt	1–3	2.00
Second molt to third molt	2–5	2.46
Third molt to fourth molt	3–6	4.00
Fourth molt to death	4–8	5.87
Complete life cycle	34–46	40.62

Number of Days for Each Life Cycle

P. citri Females

Days

38 May and June
37 June, July, and August
44 August and September
49 September, October, and November
56 November, December, and January
57 January, February, and March
42 March and April
42 April and May
365–45.62 days

Ph. gossypii Females

Days

42 July, August, and September
49 September and October
57 October, November, and December
53 December, January, and February
57 February, March, and April
42 April and May
38 May and June
43 June, July, and August
381–47.62 days

It is almost impossible to distinguish definitely the males of either species from the females until they produce the cotton cocoon a few days before the second molt. However, it is sometimes possible to distinguish the differences a few days before the cocoon is formed, as at this time the males increase in size and are somewhat larger than the females of the same age.

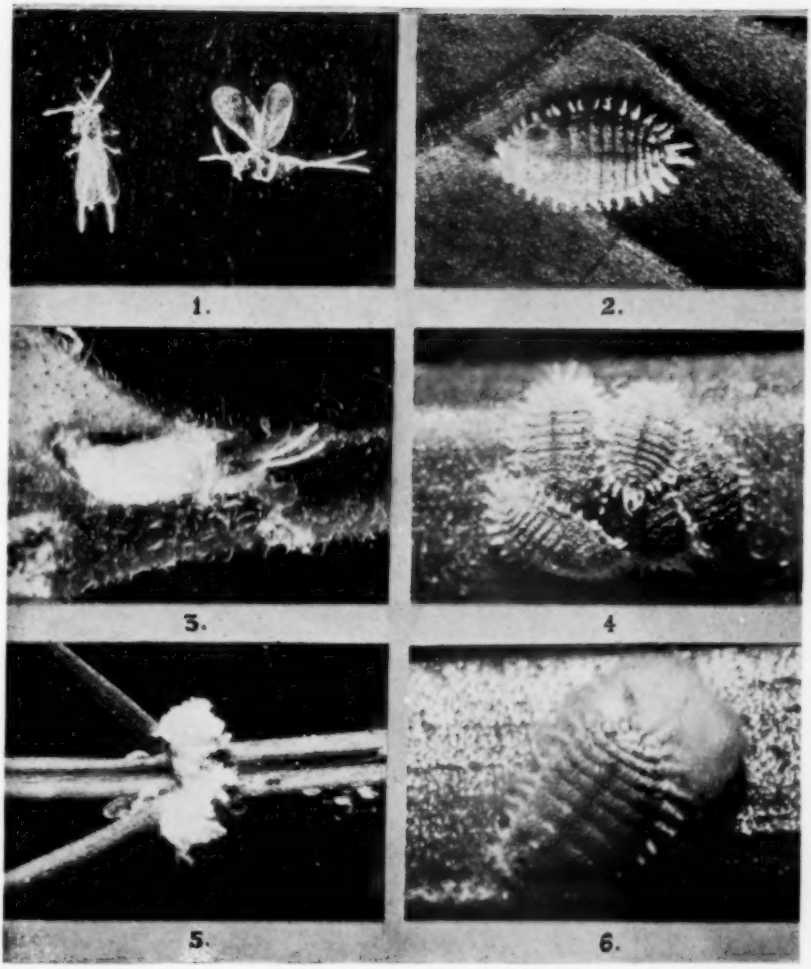
Eggs. The egg-laying period for *P. citri* varied from 5 to 23 days. From 95 to 592 eggs were laid, the average number of eggs per female being 307.10, equalling an average of 28.92 eggs per day. With *Ph. gossypii* the egg laying period varied from 6 to 14 days. From 228 to 474 eggs were laid, the average number of eggs per female being 402.33, equalling an average of 51.14 eggs per day.

The egg sac of *P. citri* is made up of a more or less loose mass of cotton with the posterior end of the female resting on top, as shown in Plate 25, Fig. 6. This would be expected from the structure of this species, as the multilocular pores secreting the egg sac are present only on the ventral side of the abdominal segments and are more numerous on the posterior segments. On the other hand, the egg sac of *Ph. gossypii* is made up more like an elongated cottony case which encloses the posterior end of the female, as shown in Plate 26, Fig. 6. The multilocular pores on this species, as the appearance of the egg sac might indicate, are on both the dorsal and ventral sides of the abdominal segments, being more numerous on the ventral side of the posterior segments.

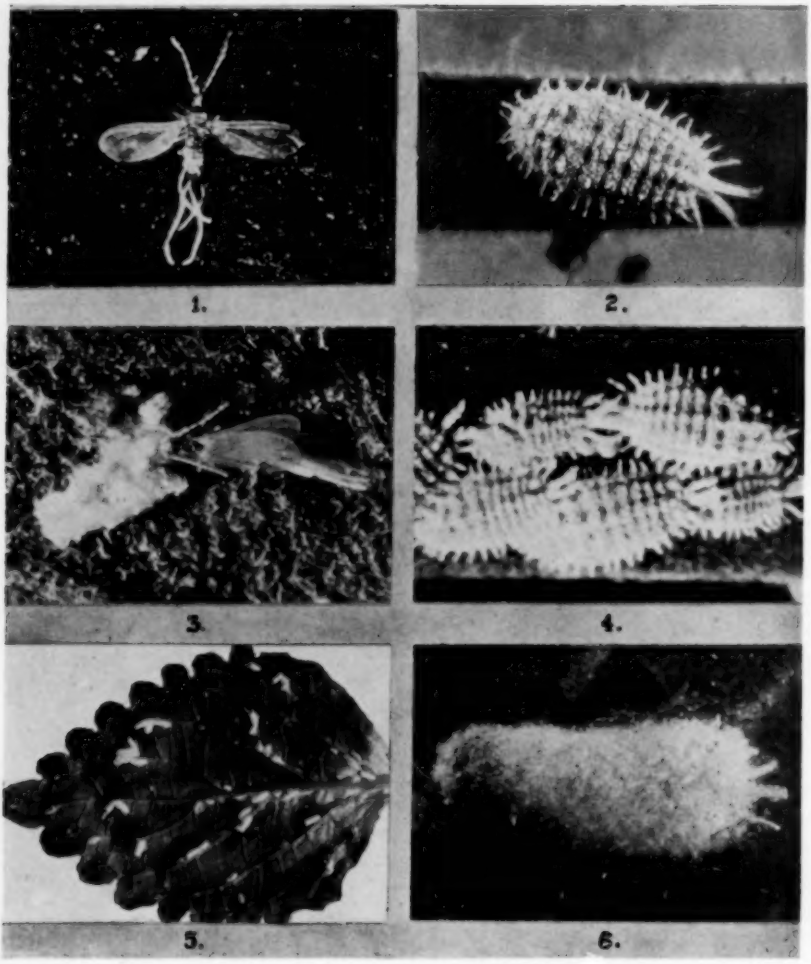
Mortality. The mortality between egg and adult apparently is a slight bit higher in *P. citri*. One female of each species, uniform in size, was placed on individual coleus plants. Both species laid about the normal number of eggs judging from the size of each egg sac. With *P. citri* 83 males and 106 females reached maturity. *Ph. gossypii* produced 143 males and 144 females at maturity.

Parthenogenesis. For this experiment females of *P. citri* were used to see if they were parthenogenetic. One female was isolated in its third stage, which laid eggs on April 4, 1931. The eggs were reared and a female isolated after its second molt, which in turn laid eggs on May 16, 1931, completing its life cycle in 42 days. Between the 16th of May and the 18th of July two more life cycles were completed with the females each time being isolated after their second molt and never coming in contact with the adult males during their life cycle. The three life cycles of the unfertilized females were 42 days, 33 days, and 30 days respectively.

Effect Upon Host. An experiment was carried on to determine the effect of each species upon its host. On August 26, 1930 three uniform



Pseudococcus citri (Risso). 1. Adult male. 2. Adult female. 3. Adult male emerging from cocoon. 4. Group of adult females. 5. Male cocoons characteristically grouped. 6. Adult female and egg sac, showing the posterior end of female characteristically on top of egg sac.



Phenacoccus gossypii (T. & Ckll.) 1. Adult male. 2. Adult female. 3. Adult male emerging from cocoon. 4. Group of adult females 5. Male cocoons characteristically scattered. 6. Adult female and egg sac, showing the posterior end of female characteristically enclosed in egg sac.

coleus plants were chosen, each 10 inches tall bearing 8 leaves. On one was placed a mature female of *P. citri* just laying its first eggs; and on the second was placed a *Ph. gossypii* female laying its first eggs, the third being used as a check plant. The first eggs of both females hatched on September 1, 1930, and by then all three plants were 10¾ inches high. By September 6, 1930 all the eggs from both species had hatched with the three plants first showing differences in size. The plant bearing *P. citri* was 11½ inches high with 12 leaves, the *Ph. gossypii* plant was 11¼ inches high with 12 leaves, and the check plant was 11½ inches with 12 leaves. Each female laid the average number of eggs judging by the egg sac of each. On September 9, 1930 both species had their first molt. On September 14th *Ph. gossypii* had its second molt, while *P. citri* had its second molt on September 15th. The third molt for *Ph. gossypii* was September 20, 1930 and for *P. citri* was September 21st. *Ph. gossypii* had its first specimens to mature and lay eggs on October 3, 1930 while with *P. citri* the first specimens matured and laid eggs on October 4th. The height of the three plants on October 3, 1930 was 13½ inches with 14 leaves for the plant bearing *P. citri*, 11¾ inches and 12 leaves for the plant with *Ph. gossypii*, and 16¾ inches with 16 leaves for the check plant. On October 3, 1930 *Ph. gossypii* first showed signs of wilting from the effects of the mealybugs. On October 15, 1930 *P. citri* first wilted. It was at this time 13¾ inches high and bore 14 leaves while the check plant was 18¾ inches high bearing 18 leaves. During the experiment the check plant grew more rapidly and was much healthier than the other two plants. With the two infested plants *Ph. gossypii* showed the most dwarfing and wilted 38 days after eggs had been laid. The plant infested with *P. citri* wilted 50 days after the eggs had been laid.

The difference between the growth and death of the two infested plants is more than likely due to the abundance of insects on each plant. The *Ph. gossypii* plant seemed to be more heavily infested. This could possibly be expected as experiments showed more *Ph. gossypii* to mature from a single female than with *P. citri*.

Recognition Characters. For some time there has been some doubt as to the identity of the *P. citri* used in these experiments, which for a while was believed to be *Pseudococcus kraunhiae* (Kuw.), the Japanese mealybug. It seems therefore advisable to point out some of the main differences that separate the two species. *P. citri* and *P. kraunhiae* are two of the few *Pseudococcus* species in the United States having a chitinized bar on the ventral side of the anal lobe. As a rule the two species have been mainly separated by the shape of the setae in

the cerarii; that is, *P. citri* has its setae more or less coming to a straight point, while with *P. kraunhiae* the setae in the cerarii end flagellated or hair-like, oftentimes curved over at the tip. This alone does not seem to be a valid character as many specimens of *P. citri* have their setae flagellated. There seem to be two main characters that differ between the two species. With *P. citri* the ventral side of the anal lobe has present 7 to 9 small tubular ducts, while on *P. kraunhiae* the number of tubular ducts are 14 to 24. On the dorsal side of *P. citri* opposite the posterior lateral cerarii is a large tubular duct with a raised rim. This duct is not very constant. On some specimens nearly all of the posterior lateral cerarii will be accompanied by this duct and on other specimens only one or two of the tubular ducts can be found; when the fewer number are present, they are usually near the preanal cerarii. In *P. kraunhiae* on the dorsal side near the posterior lateral cerarii is also found a tubular duct but distinctly without a raised rim and only slightly larger than the ducts on the ventral side. Like the duct on *P. citri* it is not constant and usually near the preanal cerarii when not abundant. It is not uncommon to find individual cerarii of *P. kraunhiae* accompanied by two such ducts.

Specimens of *P. citri* used in these experiments have been compared with specimens of *P. citri* collected by the writer on carob from San Dimas, California, and with specimens of *P. kraunhiae* on citrus from Ojai Valley, Ventura County, California, determined as *P. kraunhiae* by Professor Ferris of Stanford University. The Mississippi material corresponds with the former. Specimens of *P. citri* from these experiments were also determined by Professor Ferris as *P. citri*.

INSECTICIDAL CONTROL OF THE COMMON BLACK FIELD CRICKET (*GRYLLUS ASSIMILIS* FABR.)

By J. A. MUNRO and L. A. CARRUTH[1]

Contribution from the Department of Entomology, North Dakota Experiment Station[2]

ABSTRACT

Experiments were conducted to determine the relative values of various insecticides used in baits and as dusts for the control of the common black field cricket. Sodium fluosilicate, as used in baits, proved a most satisfactory insecticide. For use in houses, and other places where bait could not be applied satisfactorily, pyrethrum powder applied as a dust proved very effective in killing the insects.

Experiments conducted in 1931, in continuation of work begun in 1927, show the relative values of various insecticides used for com-

[1]Special assistant during 1931.

[2]Published with the approval of the Director of the Experiment Station.

bating the common black field cricket, a widely distributed field and household pest in North Dakota.

The insecticides used in the experiments with baits and in the form of dusts included sodium fluosilicate, sodium fluoride, sodium arsenite, white arsenic, Paris green, thallium sulfate, and pyrethrum. The sodium fluosilicate was a brand sold under the trade name of "L & V Fluosilicate Dusting Powder Extra Light." The pyrethrum powder was the Japanese variety (*Chrysanthemum roseum*). The thallium sulfate was a sample secured from a chemical supply house, and the sodium fluoride and arsenicals were commercial brands secured on the open market.

These insecticides were applied to crickets in screen wire cages. Materials which showed promise under cage conditions were later applied to the insects in their natural habitats.

ATTRAHENTS TESTED. Preliminary trials included the use of molasses, oranges, tomatoes, honey, Karo syrup, amyl acetate, ground meats, and cheese. Molasses proved to be the most dependable and satisfactory attrahent in baits. Amyl acetate, ground meats, and cheese were apparently of no value.

Twenty-five crickets, apparently normal, were used to each cage. These were secured more than 100 yards distant from places where the insecticides were applied. Maimed or crippled insects were discarded.

Except for the insecticides applied, the conditions within the cages approximated very closely the natural habitats of the crickets. This was borne out by the check cage test run with each series. The mortality of crickets in check cages averaged only nine per cent for the various series conducted. The crickets in check cages were supplied with a mixture consisting of bran 100 grams, molasses 16 cc, a very small portion of an orange, and water to moisten. For dusting trials in cages the crickets were given this same mixture directly after the dusting was done.

For each series of tests a shallow layer of earth was placed on the floor of each cage. The insects were counted and the proper number placed inside.

Observations on mortality of crickets in cages were made at 24-hour intervals of time. Each test was discontinued after 72 hours because it was felt that an effective measure should give the desired results within this period.

At the conclusion of each series, the cages were emptied, washed, and made ready for use again.

BAITS TESTED. A review of the literature on the subject revealed several well recommended baits. Arsenicals were chiefly listed as

poisoning agents. As these were given in field quantity, it was necessary to reduce the ingredients of the formulae to correspondingly small amounts for cage tests. The metric system of weighing was used. The following table shows the results obtained with the various baits used:

TABLE 1. MORTALITY OF CAGED CRICKETS SUPPLIED WITH BAITS

(All baits contained 100 grams bran, 95–105 cc water, and, where orange was required, only a very small portion of the fruit)

Poison	Composition of attrahents		Number of trials	Percentage mortality of crickets after:		
				24 hr.	48 hr.	72 hr.
Sodium fluosilicate	12 gm. Molasses	16 cc	4	59	86	92
Sodium fluosilicate	12 gm. Molasses	16 cc: Orange	6	61	81	88
Sodium fluosilicate	5 gm. Molasses	16 cc: Orange	4	46	75	89
Sodium fluosilicate	2½ gm. Molasses	16 cc	1	28	44	52
Sodium fluoride	5 gm. Molasses	16 cc: Orange	5	30	66	84
Sodium arsenite	12 gm. Molasses	16 cc:Orange	3	32	43	64
Sodium arsenite	6 gm. Molasses	32 cc	2	14	28	40
Sodium arsenite	5 gm. Molasses	16 cc	2	16	26	40
Sodium arsenite	5 gm. Molasses	16 cc: Orange	3	12	23	31
Sodium arsenite	4 gm. Amyl acetate	1 drop	2	10	20	30
White arsenic	12 gm. Molasses	16 cc: Orange	4	22	38	63
White arsenic	5 gm. Molasses	16cc: Orange	3	8	13	32
Paris green	6 gm. Karo syrup	16 cc: Orange	2	20	34	40
Thallium sulfate	4 gm. Molasses	16 cc: Orange	2	6	20	44

DISCUSSION. A review of the above table shows the superiority of the fluorine compounds over all other insecticides used in baits tested under cage conditions.

In comparing the mortality of crickets brought about by the sodium fluosilicate and sodium fluoride baits, there was only a slight difference in favor of the former insecticide. Comparing the price differential of the two, sodium fluosilicate was 20 per cent lower in cost.

FIELD TRIALS. Baits containing sodium fluosilicate and arsenicals were applied, over infested areas, in late afternoons and at the rate of 10 pounds per acre for the weight of bran used. Examination of the treated areas 72 hours after application showed seventy to eighty per cent of the crickets killed where a sodium fluosilicate bait was used. Poor results were obtained with arsenical baits. The general reduction in number of living crickets was the index used to check the effectiveness of

these baits. Of the various baits tested the following gave the best results in control:

Bran	50 pounds
Sodium fluosilicate	2½ pounds
Molasses (Cane)	1 gallon
Water	6 gallons

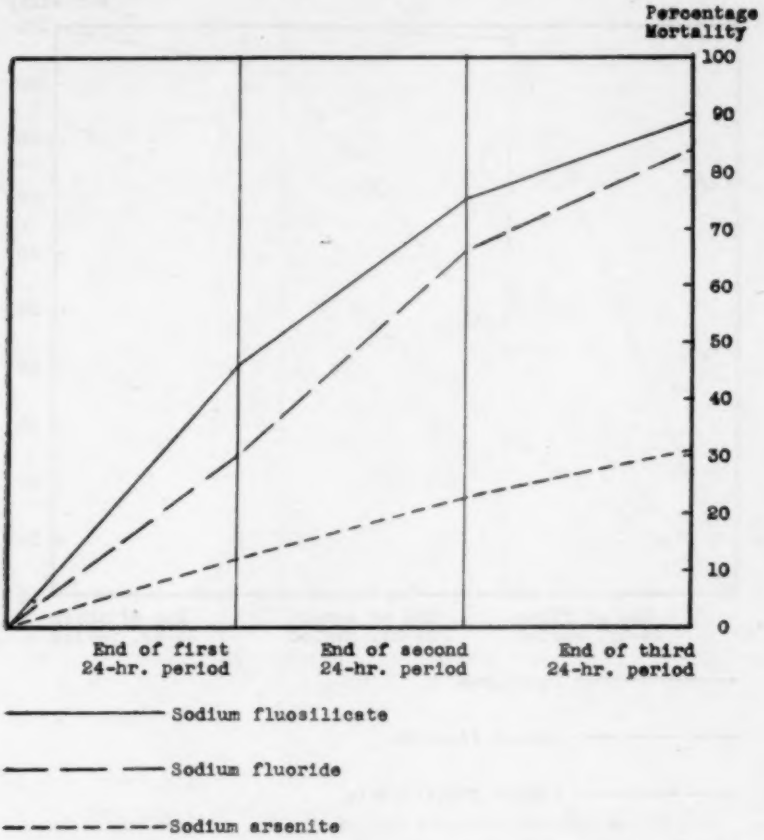


Fig. 56.—Relationship between time of exposure of three poison baits and percentage mortality of caged crickets. (Each bait contained 5 grams of poison to 100 grams of bran in the mixture.)

GRASSHOPPERS KILLED BY THE BAIT. In the use of sodium fluosilicate bait it was interesting to find other chewing insects besides crickets were killed. Various species of grasshoppers, which were moderately abundant over some of the cricket infested areas treated, were found dead at time of inspection. It was very evident that the bait was the chief

factor in bringing about this mortality, although other factors, including parasitism, may have contributed. An examination of the dead grasshoppers, taken at random from wheat stubble, showed parasitism present among some species. The species represented in order of their

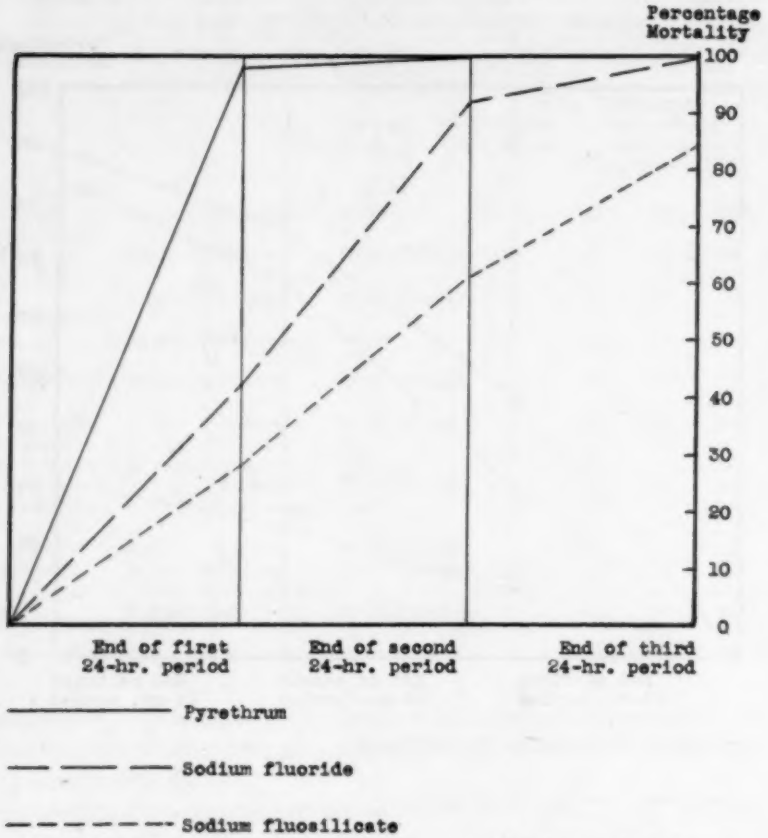


Fig. 57.—Relationship between time of exposure of three poison dusts and percentage mortality of caged crickets.

abundance included: *Dissosteira carolina* L. (19.1 per cent parasitism by *Sarcophaga kellyi* Aldrich), *Melanoplus bivittatus* Say (18.7 per cent parasitism by *Sarcophaga kellyi* Aldrich), *Camnula pellucida* Scudder, *Melanoplus femur-rubrum* DeGeer (parasitism present but not counted), *Encoptolophus sordidus* Burmeister, and *Spharagemon wyomingianum* Thomas (parasitism not apparent).

It was of rare occurrence to find a nymph or adult cricket parasitized.

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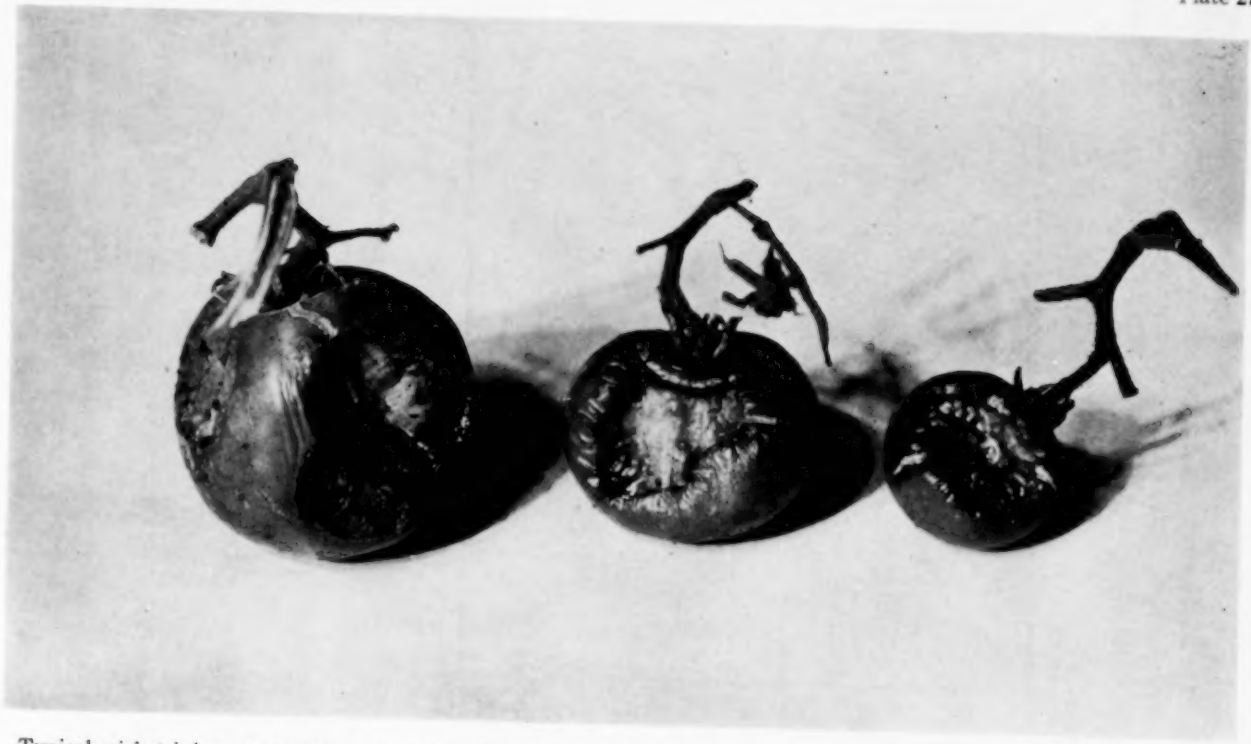

Typical cricket injury to tomatoes. Note how the crickets ate into the sides of the fruits. Occasionally 25 per cent of the crop is destroyed in this way.

Apparently this type of parasitism was not a significant factor in bringing about cricket mortality.

An examination of the dead crickets in the field showed that 14 per cent were partially eaten. This was due to cannibalism among the crickets and predatory attacks of other insects including grasshoppers. In cage tests the mortality caused by cannibalism among crickets was not significant.

Because crickets enter houses and other places where baits cannot be applied satisfactorily, other measures received attention.

Calcium cyanide granules, known under the trade name "Cyanogas", applied according to the usual recommendation for fumigation, viz., 2 pounds per 1000 cubic feet of enclosed space, gave perfect results in killing the crickets but produced no lasting protection because of re-infestation by crickets coming in from outdoors.

TABLE 2. MORTALITY OF CAGED CRICKETS DUSTED WITH INSECTICIDES

Dusted with	Number of trials	Percentage mortality of crickets after:		
		24 hours	48 hours	72 hours
Pyrethrum	2	98	100	—
Sodium fluoride	2	42	92	100
Sodium fluosilicate	2	28	66	84

The above table shows the results obtained from dusting with pyrethrum, sodium fluoride, and sodium fluosilicate under cage conditions. Pyrethrum proved the most effective.

These insecticides were applied as dusts for control of crickets in houses and under certain outdoor conditions. A small hand duster was used to facilitate the work.

For house use the dusts were blown into corners and out-of-the-way places frequented by the crickets, and for outdoor use they were blown underneath boards and other objects where the crickets congregated in relatively large numbers.

Under the conditions as stated, the pyrethrum powder gave excellent results. Examination made two hours after treatment showed the crickets to be dead or dying, many of which had escaped a short distance from the place of treatment before being overcome. So far as could be ascertained, the pyrethrum killed all the crickets with which it originally came in contact.

Gradual re-infestation of places treated indicated that the pyrethrum lost its lethal action soon after exposure to the air.

Sodium fluoride and sodium fluosilicate applied as dusts, under conditions as obtaining for the use of pyrethrum, gave a fair degree of control and apparently did not deteriorate while in use.

Conclusion

1. Sodium fluosilicate proved to be the most effective insecticide in baits used for the control of the common black field cricket.

2. Sodium fluoride ranked second to sodium fluosilicate as a poisoning agent in baits. Its use is recommended where sodium fluosilicate is unavailable.

3. Arsenicals and thallium sulfate as used in baits gave unsatisfactory control.

4. Under cage conditions, the addition of orange did not make the bait more attractive to crickets. Whether or not the addition of oranges or other fruits to baits for use under field conditions is desirable is an open question. Molasses proved a dependable attrahent in baits.

5. Pyrethrum applied as a dust quickly killed crickets in houses and under certain outdoor conditions.

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THE OLFACTORY RESPONSES OF THE COCKROACH (*BLATTA ORIENTALIS*) TO THE MORE IMPORTANT ESSENTIAL OILS AND A CONTROL MEASURE FORMULATED FROM THE RESULTS

By A. C. Cole, jr., *Ohio State University*

Abstract

Employing an improvised Y-tube olfactometer, the responses of cockroaches to some of the more important essential oils were determined. These responses were positive or negative depending upon the oil used in each case. There was also a small percentage of reverse responses, especially when the concentration of the oil was not high. The results of these tests were tabulated individually and collectively. With the results as a starting point a satisfactory bait was developed which killed the roaches in slightly more than three hours average time. This bait is also toxic to house-infesting ants providing a little sugar is substituted in the formula.

Inasmuch as cockroaches are of a fairly large size and may be secured in considerable numbers, their olfactory responses to chemical stimuli may be determined with comparative simplicity, the responses always being quite pronounced and the percentage of false movement slight.

For an olfactometer a Y-tube was employed, made of Pyrex glass one inch in diameter, eighteen inches long on the straight arm and twelve inches on each of the forks. The end of the straight tube was connected to a water suction pump by means of a piece of rubber tubing. One of the forks was joined to a bottle fitted with a two-holed rubber stopper and filled with concentrated, chemically-pure sulfuric acid. From the other hole extended a short glass tube open at the end to the atmosphere. The second fork led to a bottle containing the bait and thence to another dehydrating bottle. The light on the apparatus was maintained as constant as possible as was also the temperature without the use of special equipment.

The apparatus was thoroughly cleaned with anhydrous ether and the connections made air tight. The bait, previously diluted (1–1000) with a pure, odorless vegetable oil, was placed in the appropriate bottle. The suction was then started and a roach introduced into the straight arm by removing the rubber stopper from the unforked end. If the roach moved to the end of the baited fork a positive response was recorded and if to the unbaited end, a negative, providing it remained near the end for at least fifteen seconds. If it moved to the baited fork and then reversed direction and went into the unbaited one the recorded response was positive-negative. The same applied to the reverse condition, when it was recorded as a negative-positive response. I have termed the latter two responses *indirect responses*. The apparatus was thoroughly cleaned between each set of tests so that there could be no possibility of mixing odors.

Table 1 lists the results of the experiments. It is interesting to note that in the case of four of the oils all individuals tested reacted positively. Such definite reactions indicate extremely strong attractant properties of those oils. From previous experiments the author believes that there is very little difference between chemo-responses of starving cockroaches and those which have had food constantly, the responses, however, sometimes being slightly more pronounced to attractants in the former case.

With the best determined attractants as a basis the following bait was developed:

Gelatine, by weight	6 grams
Dilute beef broth, by volume	200 cc.
Mercuric chloride (U. S. P.)	½ gram
Attractant—Banana oil, oil of sweet orange, oil of apple, *or* oil of pineapple	1 drop (approximate)

The gelatine was dissolved in the *hot* beef broth, the mercuric chloride added and then the attractant. After cooling the medium developed a gelatinous consistancy. A very small cookie-cutter may be employed for cutting the bait into uniform-sized pieces. In this case the material, while still warm and in a liquid condition, should be poured into flat containers of desired thickness. These pieces may be indefinitely stored in tightly-sealed metal containers.

The purpose of the mercuric chloride is two-fold. It is the poison by which the cockroach is killed and it furthermore prevents the formation of colonies of bacteria and mould which might otherwise develop on the gelatine. The advantage of using a gelatine base lies in the fact that the mercuric chloride as well as the attractant is distributed uniformly thruout, and furthermore that the bait is in a solid state. The addition of a weak solution of beef broth creates a food for the roach and is an essential part of the formula. The bait may be placed in flat dishes, set on the floor and left there overnight. The consumption is not great for

TABLE 1. TABULATED RESULTS OF THE ATTRACTANT TESTS

Oil	No. pure pos.	No. pure neg.	No. indirect responses
Cumin	0	58	17
Eucalyptus	0	75	0
Pennyroyal	0	59	16
Parsley	0	60	15
Pimento	0	62	13
Caraway	13	51	11
Mustard	1	53	21
Spike	0	64	11
Rosemary	0	57	18
Cubeb	0	61	14
Sweet orange	71	0	4
Rice	35	40	0
Fennel	21	54	0
Bitter almond	1	74	0
Pineapple	74	0	1
Apple	75	0	0
Peppermint (dil.)	63	0	12
Peppermint (con.)	0	75	0
Juniper	0	71	4
Wintergreen (dil.)	71	0	4
Corriander	0	58	17
Cedarwood	0	57	18
Sasafras	75	0	0
Thyme	0	64	11
Nutmeg	75	0	0
Banana	75	0	0
Sandlewood	9	46	20
Citronella	0	75	0
Horse-radish	0	75	0
Mace	3	59	13
Cassia	0	56	19
Wormseed	0	60	15

the roaches eat very little of the material. This bait is also toxic to house-infesting ants and is best used in this case with the addition of about a teaspoonful of sugar. In this case water may be substituted for the beef broth.

The lethal period is illustrated in Table 2. It is to be noticed that the bait does not afford an instantaneous poison but rather is one which kills in an average of three hours.

TABLE 2

Number	Time placed with poison	Time of death	Lethal period
1	8:07 P.M.	10:11 P.M.	2 hrs., 4 min.
2	8:07 P.M.	10:38 P.M.	2 hrs., 31 min.
3	8:07 P.M.	10:47 P.M.	2 hrs., 40 min.
4	8:07 P.M.	10:52 P.M.	2 hrs., 45 min.
5	8:07 P.M.	11:15 P.M.	3 hrs., 8 min.
6	8:07 P.M.	11:16 P.M.	3 hrs., 9 min.
7	8:07 P.M.	11:30 P.M.	3 hrs., 23 min.
8	8:07 P.M.	12:05 P.M.	3 hrs., 3 min.
9	8:07 P.M.	12:17 P.M.	4 hrs., 10 min.
10	8:07 P.M.	12:45 P.M.	4 hrs., 38 min.
11	8:07 P.M.	12:53 P.M.	4 hrs., 46 min.
12	9:45 P.M.	1:27 A.M.	4 hrs., 22 min.

PRELIMINARY EXPERIMENTS ON THE TOXICITY OF CERTAIN COAL-TAR DYES FOR THE SILKWORM

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ABSTRACT

Aqueous solutions of 21 representative coal-tar dyes were administered to silkworms by mouth and by injection. The 11 acid dyes and 6 of the 10 basic dyes did not kill the larvae by either method of administration at a dose of 0.05 mg. per gram of body weight. The 4 lethal basic dyes were: (1) malachite green, (2) safranin bluish, (3) brilliant green, and (4) crystal violet. "By mouth" their relative toxicity was in the order just given, malachite green being the most toxic. By injection the order was (3), (1), (4), (2).

Since malachite green is more toxic than acid lead arsenate for the silkworm, it might be desirable to use it for the coloring of white arsenicals and fluorine compounds to comply with such laws as may be enacted on the coloring of insecticides. Malachite green and other toxic dyes, being soluble in water and not strongly adsorbed by lead and calcium arsenates, might be added to the arsenicals in the form of adsorption compounds with clays, such as bentonite. When the concentration of the dye on the clay is such that it can not be washed out with water, it may still be liberated in the alimentary tract of the insect.

The colorless, insoluble leuco and color bases of malachite green were not toxic to the silkworm.

Neutral red, when administered by mouth, colored the integument of third-instar silkworms. The color was retained throughout the remainder of the larval stage.

The suggestion is made that vital stains might be used for the identification of insects for experimental purposes.

A description of the construction and operation of a simple injection pipette is given. It was used not only for the injection of dyes into silkworms, but also for the injection of organic liquids into the grasshopper, *Melanoplus differentialis*. Methyl alcohol, ethyl alcohol, and ether, having only a temporary effect, might be used as solvents for poisons insoluble in water. The median lethal dose of nicotine by injection into fifth-instar silkworms was about 0.0015 mg. per gram.

In 1927, when the writer[1] was searching for arsenical substitutes, a survey of the toxicity of water-soluble, coal-tar dyes was made. The results are now of some interest because of proposed legislation requiring the coloring of insecticides. Since it is probably feasible to color arsenical or fluorine compounds with coal-tar dyes, it might be desirable to choose those dyes that have insecticidal value. The present paper gives the results of feeding and injecting the silkworm with aqueous solutions of representative coal-tar dyes. The method of injection is described and discussed in detail.

APPARATUS AND METHODS.—Silkworms of the fourth instar were fed measured volumes of aqueous solutions of coal-tar dyes. Droplets of the solutions were run out upon the tip of a microburette. They were removed from the tip by a platinum needle and were placed on the mouth parts of the silkworm, which was held in the fingers under a binocular microscope. In most cases the drops were completely imbibed by the insects. Silkworms that failed to drink or did not imbibe the entire dose were discarded. The apparatus and technic used in the present investigation were the same as those described in detail in an earlier paper (*1*).

Fifth-instar silkworms were injected with measured volumes of aqueous solutions of coal-tar dyes. A piece of capillary tubing (length, 15 cm.; bore, 0.72 mm.) which was drawn to a fine tip was used to measure the solutions and to inject them into the body cavity. Several workers have been interested in this simple injection pipette, not only for the purpose of making injections, but for measuring small volumes of liquid. It is very easily made as follows: One end of a rubber tube is held in the mouth and the other is attached to the capillary tube. The other end of the capillary tube is heated in the flame of a Bunsen burner until the capillary is closed. Then a bubble is blown in the heated end of the tube and is grasped by forceps and pulled out. This tip, being too thick, is sealed and the point of constriction between the tube

[1]The writer was assisted by R. S. Filmer, now Associate Entomologist, New Jersey Agricultural Experiment Station.

and tip is heated. A bubble is blown at this point and the tip is pulled out. This process is repeated, if necessary, until a tip of satisfactory length, thickness, and diameter of orifice is obtained. The dimensions of the tip depend on the species of insect to be injected. The tip should be thick enough to penetrate the intersegmental membrane without breaking and thin enough to obviate bleeding from the puncture when it is withdrawn from the body cavity. The diameter of the orifice should be as large as possible to offer a minimum of resistance to the passage of liquid through it. The bubbles are blown for the purpose of making the orifice large relative to wall thickness. If necessary the tip can be ground on a fine water stone to a smooth bevel edge. The dimensions of a tip suitable for injecting fifth-instar silkworms were as follows: Length, 1 cm.; bore of orifice, 0.10 mm.; outside diameter at orifice, 0.16 mm. If it is found difficult to obtain a suitable tip by this method, a short piece of ordinary glass tubing can be fused onto the end of the capillary tube, and the tip may be drawn from the former without blowing bubbles.

The injection pipette is easily calibrated by weighing mercury or water from a measured length of the capillary and calculating the volume with the aid of tables of density. In the case of the pipette used in the present experiments, 1 cm. length of capillary was equivalent to 0.00408 cc. The bore of a short length of capillary tubing is not likely to vary so much that the calibration will be seriously in error in a portion of its length. However, it is well to make certain of the uniformity of the bore by weighing mercury from different portions of its length. The bore of the capillary tubing to be chosen will, of course, depend on the volume of liquid to be injected and on the precision desired.

The pipette used by the writer was provided with a paper scale, made by sticking a strip of millimeter cross-section paper along the length of the pipette with a wider strip of black, lantern-slide binding paper. This scale is obviously not so accurate and permanent as graduations etched on the glass would be, but it is satisfactory for experiments in which other errors are greater than the error of measurement. Graduated thermometer tubing can be employed for the measurement and injection of very small volumes, if the temperature of the tube can be held constant.

For the purpose of making injections, one end of a rubber tube 50 cm. long was attached to the pipette and the other to a short-stemmed glass funnel 5 cm. in diameter. The funnel was supported in a ring on a heavy stand in such a position that the lips could be forced against it,

and maximum cheek pressure developed. The stand was clamped to the table.

An injection was made as follows: A larva was weighed to the nearest decigram and the length of capillary corresponding to the dose was found by slide rule.[2] The pipette having been filled by suction to a certain mark on the scale, a rubber band around the tube was set at the calculated distance from the starting point to mark the end point plainly. The larva was held, lateral aspect up, with the posterior end between the ends of the thumb and forefinger of the left hand. With the lips in the funnel and with the pipette held like a pencil in the right hand, the point of the glass needle was directed cephalad and parallel to the longitudinal axis of the larva and was placed in the fold of the intersegmental membrane between abdominal segments 6 and 7 just dorsad of the spiracle level. The needle was then forced through the integument for a distance of 2 or 3 mm. The breaking of the integument was felt as the needle entered the body, and instantly full cheek pressure was applied, not only to drive the solution into the larva against the resistance of the small bore of the needle and of the blood pressure of the larva, but also to prevent blood from rushing into the pipette. Cheek pressure was regulated so that the meniscus of the capillary column fell slowly and steadily. When it reached the position of the rubber band, the worm was jerked away from the needle. The method of injection is illustrated in Plate 28.

More than half the injections were made without visible loss of blood from the puncture. Only such injections were considered satisfactory. A slight loss of blood would not be objectionable, if it were not probable that some of the dose might escape with the blood. Hockenyos and Lilly (*13*) recently described a method of injecting large larvae by the use of a tuberculin syringe. The present writer has not given the tuberculin syringe a thorough trial because in preliminary tests it always caused serious bleeding of silkworms. Puncturing the integument before inserting the syringe needle, as recommended by Hockenyos and Lilly, may overcome this difficulty. Nevertheless, the present writer prefers the capillary pipette for injections because its smaller bore permits the accurate measurement of small volumes and extends the number of species that can be injected quantitatively. For example, the writer has injected successfully a large series of grasshoppers weigh-

[2]For example, the weight of the insect was multiplied by a constant, 12.2, to obtain the number of millimeters of capillary corresponding to a dose of 0.05 mg. per gram of a solution containing 10 grams of dye per liter. The volume injected for this dose was therefore 0.005 cc. per gram of insect. The larvae weighed about 1 gram.

Method of injecting fifth-instar silkworms.

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ing from 0.3 to 0.6 gram. For these and other injections a volume of 0.005 cc. per gram was chosen. Since the tuberculin syringe is graduated to 0.01 cc., it is evident that it could not be used with any accuracy for the injection of this volume into small grasshoppers. No doubt a larger volume per gram can generally be used for aqueous solutions. Hockenyos and Lilly injected not less than 0.01 cc. per gram into larvae weighing from 2.5 to 6 grams. When substances insoluble in water are to be injected, organic solvents or emulsions must be used, and since the solvent itself will have some effect on the insect, the volume injected per gram of body weight should be small.

In the above-mentioned experiments with grasshoppers, *Melanoplus differentialis* Thos., the writer found that methyl alcohol, ethyl alcohol, and ether immobilized the insects temporarily. Since the insects recovered completely in a short time, these liquids might be used as solvents for toxic compounds, such as rotenone, that are insoluble in water. Other liquids having little or no permanent effect on the grasshoppers were butyl acetate, amyl acetate, acetaldehyde, oleic acid, and turpentine. The grasshoppers were killed by 34 of the 42 organic liquids tested.

RESULTS OF FEEDING AND INJECTION EXPERIMENTS.—Aqueous solutions of the following dyes were injected into silkworms and those marked with an asterisk were also administered by mouth. The classification of the dyes is based on that given by Conn (7), and the structural formulae of most of them can be found in his book.

ACID DYES

Azo dyes
- Anilin yellow
- *Biebrich scarlet
- *Bordeaux red
- *Congo red
- Orange G

Quinone-imide dyes
- *Nigrosin (water soluble)

Xanthene dyes
- *Eosin Y
- *Fluorescein
- Rose bengal

Nitro dyes
- *Naphthol yellow

Phenylmethane dyes
- Methyl blue

BASIC DYES

Azo dyes
- Chrysoidin R

Quinone-imide dyes
- *Meldola's blue
- *Neutral red
- *Safranin bluish
- *Safranin O

Xanthene dyes
- *Pyronin (Schultz No. 469, 4th ed.)
- Rhodamine B

Phenylmethane dyes
- *Brilliant green
- *Crystal violet
- *Malachite green

In the preliminary feeding tests solutions of 1 gram per liter were used and the larvae were allowed to drink as much as they could take. The doses were not greater than 0.07 mg. per gram and were usually about

0.05 mg. per gram. The solution of each dye was fed to five larvae. At these dosages only the following four dyes killed the larvae: Brilliant green, crystal violet, malachite green, and safranin bluish. Accordingly these dyes were tested again, predetermined doses being fed. Immediately after each larva had taken its dose, it was placed in a Petri dish with fresh foliage and the dishes were placed in an incubator at 30°C. The results are given in Table 1.

TABLE 1. EFFECT OF FEEDING AQUEOUS SOLUTIONS OF BASIC DYES TO FOURTH-INSTAR SILKWORMS

Dye	Number of larvae	Concentration of solution Grams per liter	Dose Mg. per gram	Result
Malachite green	4	10	0.100	All died.
	5	10	0.050	Do.
	5	10	0.025	Do.
Safranin bluish	6	1	0.050	All died.
	7	1	0.025	All recovered.
	8	1	0.010	Do.
	10	10	0.050	All died.
Brilliant green	5	10	0.100	All died.
	20	10	0.050	14 died, 6 recovered.
Crystal violet	5	10	0.100	All died.
	5	10	0.050	All recovered.

Preliminary injection tests were made with solutions of 10 grams per liter and a dose of 0.05 mg. per gram. Again only the four dyes mentioned above killed the larvae. The results of further tests of these dyes are given in Table 2.

TABLE 2. EFFECT OF INJECTING AQUEOUS SOLUTIONS OF BASIC DYES INTO FIFTH-INSTAR SILKWORMS

Dye	Number of insects	Concentration of solution Grams per liter	Dose Mg. per gram	Result
Brilliant green	5	10	0.050	All dead in 3 hours.
	1	10	0.025	Nearly dead in 3 hours.
Malachite green	5	10	0.050	Nearly dead in 5 hours.
	5	10	0.025	All dead in 24 hours.
Crystal violet	5	10	0.050	All dead in 24 hours.
	5	10	0.025	Nearly dead in 24 hours.
Safranin bluish	5	10	0.100	All dead in 24 hours.
	5	10	0.050	All dead in 24 hours.
	10	10	0.025	Dying in 24 hours.
	10	10	0.010	All recovered.

The numbers of insects and doses used were too few for accurate determination of the median lethal doses and the relative toxicity of the

four toxic dyes. Moreover, since these dyes were not of the same degree of purity, and since the acid radicals of their salts were different, their toxicity can not be strictly compared. According to the manufacturer who supplied the dyes, the malachite green was an oxalate with a dye content of 78 per cent; the safranin bluish was a chloride with dye content of over 90 per cent; the brilliant green was a sulphate with dye content of 84 per cent; and the crystal violet was a chloride with dye content of 90–95 per cent. With these facts in mind, the arrangement of the four toxic dyes in Table 3 in the apparent order of their toxicity must be regarded as unreliable. However, Table 3 shows, as would be expected, that the toxicity of the dyes "by injection" is greater than that "by mouth," and indicates that the order of toxicity "by injection" is not the same as that "by mouth." Furthermore, Table 3 shows that the median lethal doses, although not definitely delimited, are of the same order of magnitude as those for certain arsenicals (*2*, *4*). It may be concluded, therefore, that certain coal-tar dyes, being about as toxic as the arsenicals, are worthy of consideration as arsenical substitutes or for the coloration of arsenicals.

TABLE 3. RELATIVE TOXICITY OF CERTAIN DYES AND ARSENICALS FOR THE SILKWORM

By mouth (fourth instar)		By injection (fifth instar)	
Compound	Median lethal dose Mg. per gram	Compound	Median lethal dose Mg. per gram
Malachite green	About 0.025	Brilliant green	Less than 0.025
Safranin bluish	Between 0.025 and 0.05	Malachite green	Less than 0.025
Brilliant green	About 0.05	Crystal violet	Less than 0.025
Crystal violet	Between 0.05 and 0.10	Safranin bluish	About 0.025
Arsenic trioxide	Between 0.015 and 0.020	Arsenic trioxide	Between 0.007 and 0.010
Arsenic pentoxide	Between 0.020 and 0.040	Arsenic pentoxide	Between 0.008 and 0.012
Acid lead arsenate	About 0.09		

During the course of these experiments observations were made on the coloration of the larvae by the dyes and on the effect of the dyes on the heart beat and behavior of the insects. A few of the more interesting observations will be described here.

Neutral red, which was not expected to be toxic because it is used as a vital stain, was the only dye tested that changed the external color of the silkworm. When this dye was administered to third-instar silkworms by mouth, the larvae assumed a pinkish tinge in from one-fourth to one-half hour after taking the dose. On the following day the larvae, which behaved normally in every way, were of a deeper shade of pink. After molting to the fourth instar they were still pink. Since they appeared

yellow by transmitted light, as normal larvae do, it was not likely that the dye was in the blood. It had probably accumulated in the hypodermal cells and other tissues. The larvae retained their pink color in the fifth (last) instar. One larva was inflated by T. E. Keleher, Bureau of Entomology, and was retained by the writer for one or two years as evidence for pink silkworms. The writer describes this case of permanent staining because it might be applied to the indelible marking of insects for experimental purposes. Even if the insect is highly pigmented, neutral red or some other vital stain might color the intersegmental membranes.

The four lethal dyes caused the heart of the silkworm to stop pulsating long before the insects ceased to move and to respond to stimuli. The writer (*3*) has noted that this effect is produced by sodium fluosilicate but not by lead arsenate. However, when treatment with dyes caused the heart to stop beating, death did not always follow. Safranin O and orange G, when injected, stopped the pulsations of the heart completely, but by the next day the larvae had recovered and the heart was beating again. On the other hand, a dye may have a toxic effect without affecting the heart. Rhodamine B, when injected, affected the larvae to such an extent that they were unable to crawl, but the heart, stained red, continued to beat. The larvae recovered completely overnight.

Some of the toxic dyes, when injected, caused the larvae to regurgitate. All lethal dyes caused the excrement to become moist or partly fluid. This effect is not peculiar to the arsenicals, but is produced by nearly all substances that kill the silkworm. Wigglesworth (*21*) has recently argued that the function of the rectal glands is to absorb water from the contents of the rectum. Perhaps the general diarrheal effect of poisons on the silkworm is caused by their interference with the functions of the rectal glands.

Discussion.—Little is known about the toxicity of coal-tar dyes for insects, but their action on bacteria has been studied extensively in connection with chemotherapy and bacteriological technic. The reading of a small part of this literature has convinced the writer that the relative effectiveness of dyes for bacteria and the silkworm is much the same. Therefore, relationships that have been found between chemical structure of dyes and bactericidal action may serve as a guide in searching for toxic dyes or other insecticidal organic compounds.

In 1926 Coplans and Green (*8*) drew the following generalizations from the work of previous investigators in the field of dyestuff therapeutics:

"1. Basic dyestuffs, i. e., those which contain amido or alkylamido groups without counterbalancing acidic groups, more especially those of the triphenylmethane series, have for the most part a powerful bactericidal action, but are also strongly toxic for the animal organism.

2. Acidic dyestuffs, i. e., those which contain strongly acidic groups, such as the HSO_3 group (whether amido or alkylamido groups are present as well or not) are in corresponding concentrations innocuous to the organism but also in general non-bactericidal."

These generalizations are in line with the present writer's results; i. e., that only basic dyes were markedly toxic and that the triphenylmethane dyes were the most toxic of the basic dyes tested against the silkworm.

Fairbrother and Renshaw (*11*), on the basis of very extensive experiments on the antiseptic action of coal-tar dyes, found that acid groups of any description are unfavorable to antiseptic action, or, in other words, that acid dyes are not toxic. They observed that dyes that show marked antiseptic action contain one or more amino groups in the molecule. They believed that toxicity depends on the state of dispersion of the dye in solution as well as on chemical constitution. The crystalloid dyes are more toxic than the dyes that form colloidal solutions.

Among the triphenylmethane dyes Fairbrother and Renshaw found, as did the present writer, that malachite green and brilliant green are more toxic than crystal violet. The molecules of the two former compounds are simpler than that of the latter. Molecules more complex than those of crystal violet were less toxic. For the triphenylmethane series they concluded that the most toxic compounds have two aminobenzene nuclei linked to an aliphatic carbon atom in para positions to the amino groups.

Fairbrother and Renshaw prepared and tested the chloride, tartrate, citrate, oxalate, and arsenite of crystal violet. One would suppose that the arsenite would be much more toxic than the other salts, but such apparently was not the case, for it was concluded that the antiseptic property was not much influenced by the type of acid radical. It would be interesting to know whether malachite green arsenate, patented by Lieske and Schepss (*14*) as an insecticide, fungicide, etc., is more toxic to insects than malachite green oxalate, which was tested by the writer.

Another striking similarity between the results of the writer and those of Fairbrother and Renshaw was found among the safranin dyes. Their safranin T was probably the same as the writer's safranin O and their

methylene violet was probably the same as the writer's safranin bluish. Against bacteria and the silkworm the latter compound was decidedly more toxic than the former, yet the only difference in the constitution of the two dyes is in the location of the two methyl groups. In safranin O they are attached to the benzene ring, whereas in safranin bluish they replace hydrogen in one of the amino groups. Fairbrother and Renshaw concluded that alkyl substitution in the aromatic nuclei tends to reduce antiseptic action. Alkyl substitution in the amino groups also tends to reduce antiseptic action to a lesser extent. Therefore, if the parallel between bactericidal and insecticidal action holds, phenosafranin, which contains no methyl groups, should be more toxic to insects than safranin bluish.

As a stomach poison malachite green appeared to be the most toxic of the dyes tested by the writer. It also happens to be the only dye mentioned in the literature as being a promising insecticide. In 1899 Celli and Casagrandi (*5*) reported tests of a large number of substances as culicine larvicides. A malachite green was the most toxic of 22 coal-tar dyes. Malachite green was the only dye considered by McAlister and Van Leeuwen (*15*) to be worthy of further study as an arsenical substitute for the control of the codling moth.

The writer does not believe that malachite green or any other coal-tar dye is likely to take the place of arsenical insecticides. A promising organic stomach poison should have several characteristics that are lacking in the coal-tar dyes. In the first place, it should be much more toxic to insects than the arsenicals because it is sure to be more expensive. Malachite green is only a little more toxic than acid lead arsenate and falls far below nicotine, rotenone, and the pyrethrins in toxic value. For example, the writer estimated the median lethal dose of nicotine for the fifth-instar silkworm by injection to be about 0.0015 mg. per gram, whereas the M. L. D. for malachite green is a little less than 0.025 mg. per gram. By mouth the M. L. D. of rotenone for the fourth-instar silkworm is about 0.003 mg. per gram (*18*), whereas the M. L. D. of malachite green is about 0.025 mg. per gram. Celli and Casagrandi (*5*) found that culicine mosquito larvae survived in solutions of malachite green more dilute than 1:5,000, whereas, according to Davidson (*9*), most of the larvae died in a 1:2,300,000 solution of rotenone.

Malachite green and other toxic coal-tar dyes have the further disadvantage of being easily soluble in water. It was therefore logical to test the insoluble color base and leuco base of malachite green.[3] By the

[3]Prepared by J. T. Scanlan, Bureau of Chemistry and Soils.

use of the sandwich method with fourth-instar silkworms (*4*) it was found that the larvae were not affected by the largest doses taken, 0.5 mg. per gram. These compounds may therefore be considered nontoxic to the silkworm. Another compound, tetramethyldiaminodiphenylmethane, which is probably the leuco base of a dye, was also nontoxic to the silkworm.

It seems that if coal-tar dyes are to be used as stomach poisons, they must be applied in the form of a salt, which may be rendered more or less insoluble by adsorbing it on an insoluble powder, such as charcoal or clay. Such preparations might be useful if the dye is not washed out by rain and yet is liberated by the juices of the alimentary tract of the insect. The writer has made a number of water-stable malachite-green preparations and has tested some of them against silkworms. Opportunity has been lacking to carry out the tests in such a way that the percentage of dye liberated in the alimentary tract can be estimated. However, since silkworms were killed by malachite green-clay and were not killed by malachite green-charcoal, it may be assumed that a considerable portion of the dye adsorbed on the clay was liberated in the alimentary tract, because the clays alone were not toxic. According to Michaelis and Rona (*16*) the mechanism of adsorption of dyes by charcoal is different from that by clays. Charcoal adsorbs both positive and negative ions of acid and basic dyes, whereas clays adsorb only the basic dyes by exchange of ions. The latter process might be expected to be reversible under the proper conditions. Charcoal has been tested extensively as an antidote for poisons (*10*, *12*). Since it will adsorb and render harmless poisons introduced into the alimentary tract of mammals, it is not to be expected that poisons would be released from it in the gut of insects. On the other hand, Clowes and Walters (*6*) found that certain alkaloids exert their characteristic effects on dogs, cats, and rats when adsorbed on Lloyd's reagent (a clay) so that they could not be washed out with water. Bentonite was the most promising clay for the adsorption of malachite green in the writer's experiments. The quantitative study of the liberation of poisons from clays in the gut of insects is fundamental for the development of the use of water-soluble poisons as stomach-poison insecticides. Toxic dyes are particularly suitable for such investigations because they can be easily determined colorimetrically.

At the request of the writer F. E. Dearborn, of the Insecticide Division, Bureau of Chemistry and Soils, made a few experiments on the coloring of acid lead arsenate and calcium arsenate with malachite green and brilliant green. The dyed arsenicals, after being thoroughly washed

with water and dried, were only weakly colored a bluish gray. Evidently these dyes are not strongly adsorbed by the arsenicals. By adding to the arsenicals malachite green adsorbed on bentonite it might be possible to color the arsenicals blue without reducing the insecticidal effect and at the same time to confer fungicidal properties on the mixture. Schmidt (*17*) found that malachite green and brilliant green are extraordinarily toxic to a number of fungi. Truffaut and Pastac (*19*) also rated these dyes highly, but found auramine, a yellow dye, even more toxic, as did Fairbrother and Renshaw (*11*) for bacteria. Using auramine 00 at 1:1,000 with a sticker, Truffaut and Pastac obtained good results in the field for the control of diseases of the grapevine.

The writer realizes that the coloring of arsenicals as suggested above would necessitate extensive, diverse, and long-continued tests of the new mixtures to learn how to use them to the best advantage. Even if the toxicity of the mixtures is practically the same as that of the arsenicals alone, insecticidal effectiveness in practice might be influenced by the effect of the colored residues on the behavior of the insect. Van der Meulen and Van Leeuwen (*20*) observed that the Japanese beetle ate foliage sprayed with their green lead arsenate more freely than that treated with white lead arsenate. It must also be kept in mind that malachite green and brilliant green are toxic to man and animals. For example, Coplans and Green (*8*) killed mice by subcutaneous injections of brilliant green at 0.05 mg. per gram.

One manufacturer is coloring lead and calcium arsenates pink and green with less than 1 per cent of acid dyes which are probably not toxic. In bulk these colored arsenicals can be easily distinguished from flour, but on foliage the residues were so nearly white that uninformed observers could not distinguish them from those of white arsenicals. One sample of lead arsenate was colored pale green by a dye that is readily washed out by water. Not a trace of color could be seen in the residues of this sample on foliage. It would seem, therefore, that legal requirements can be met immediately with the least disturbance to spray practices by the coloring of arsenicals with nontoxic dyes that would be completely washed out of the arsenical in the spray tank. Later attempts can be made to improve the effectiveness of arsenicals and to add fungicidal properties by the use of toxic dyes adsorbed on a suitable carrier.

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A COMPARISON BETWEEN ROTENONE AND PYRETHRINS AS CONTACT INSECTICIDES[1]

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ABSTRACT

The toxicity of derris extract, pure rotenone, and pyrethrum extract to honey bees and aphids were compared. The tests were carried out under laboratory conditions during the summer of 1931. Large differences in the toxicity to the two insects were observed.

During the last few years various extracts of pyrethrum flowers, derris, and cubé roots have been indiscriminately advocated as contact poisons against all kinds of insects; the former primarily on account of its pyrethrin content (1, 9, 10) and the latter two on account of their rotenone content (2, 3, 4, 8). While investigating the feasibility of incorporating the above mentioned toxic principles into oil and wax sprays (5, 7), distinct and appreciable differences in their toxicity to different insects were observed. It became clear to the writers that should the tests be based only on one or two insects, erroneous and incorrect conclusions might be drawn concerning the general efficiency of the resultant insecticide. At the time of the above investigation two kinds of insects, aphids and honey bees, were available in sufficiently large numbers to carry on substantial testing. These two insects have been employed all along in our laboratories as "indicators" for testing various external poisons. In order to study the relative differences in toxicity of rotenone and pyrethrum, a series of experiments on the above two insects were conducted during the summer of 1931 under atmospheric conditions prevailing in the laboratory.

EXPERIMENTAL. The tests consisted of spraying aphids and honey bees with various concentrations of the following three ingredients:

1. Acetone extract of pyrethrum flowers containing about 0.9% pyrethrins.
2. Acetone extract of derris root containing about 3.0% rotenone.
3. Pure rotenone obtained from cubé root.

The pyrethrin content was analyzed by the method suggested by Gnadinger and Corl (6). The analysis of rotenone was supplied by a commercial concern who furnished us with both derris root and pure rotenone. The concentrated extracts of pyrethrum and derris were diluted with water to desired concentrations just before spraying. The

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rotenone was first dissolved in acetone (1 gm. in 100 cc.) and then diluted with water for spraying. The results were based on both, the concentration of flowers or root and the active principles. No spreader was added to any one of the three ingredients in order to obtain a direct correlation between the insecticides applied under the same conditions.

TESTS ON HONEY BEES. Bees (*Apis mellifera* Linn.) were transferred to paraffined wire cages, measuring about 5 inches in diameter and 3.5 inches deep and provided with trap doors thru which the insects came in but were unable to get out. A cage contained from 30 to 40 bees, and several cages were used for each test. Each cage was sprayed with 20 cc. spray solution, delivered at approximately 10 pounds pressure. The excess spray was shaken off from the cages and allowed to dry for about 15 minutes. Honey, mixed with 50 per cent distilled water was then fed to the bees. After twenty-four hours the total number of bees and those dead were counted and the per cent kill calculated. Checks consisting of water, 0.5% and 1.0% acetone were used.

TABLE 1. TESTS WITH ROTENONE DISSOLVED IN ACETONE AS A CONTACT POISON ON HONEY BEES

Dilution of rotenone in gms. to cc. water	Total No. of bees tested	No. of bees dead after 24 hours	% kill
1:2,500	141	141	100.0
1:5,000	193	144	74.5
1:10,000	371	248	66.8
1:20,000	378	101	26.7
1:40,000	141	27	19.1
1:80,000	234	15	6.4
Check (1% acetone)	389	8	2.0
Check (0.5% acetone)	148	0	0.0
Check (water)	212	5	2.4

TABLE 2. TESTS WITH ACETONE EXRTACT OF DERRIS ROOT CONTAINING ABOUT 3% ROTENONE AS A CONTACT POISON ON HONEY BEES

Dilution of derris in gms. root to cc. water	Approximate dilution of rotenone	Total No. of bees in cages	No. of bees dead after 24 hours	% kill
1:400	1:13,200	130	130	100.0
1:800	1:26,400	132	92	69.6
1:1,600	1:52,800	165	16	9.7
1:3,200	1:105,600	180	6	3.4

TABLE 3. TESTS WITH ACETONE EXTRACT OF PYRETHRUM FLOWERS CONTAINING 0.9% PYRETHRINS AS CONTACT POISON ON HONEY BEES

Dilution of pyrethrum in gms. flowers to cc. water	Approximate dilution of pyrethrins	Total No. of bees in cages	No. of bees dead after 24 hours	% kill
1:400	1:44,000	112	100	89.3
1:800	1:88,000	129	109	84.5
1:1,600	1:176,000	217	108	50.0
1:3,200	1:352,000	277	124	44.7

A comparison of the results presented in Tables 1, 2, and 3 reveals the fact that pyrethrum extract in dilute solutions is much more toxic to honey bees than is either derris extract or pure rotenone. A dilution of 1 gm. of flowers to 1600 cc. water, equivalent to a dilution of 1:176,000 pyrethrins (Table 3) gave 50% kill while a similar dilution of derris root equivalent to 1:52,800 dilution of rotenone (Table 2) gave only 9.7% kill. Again, a dilution of 1:3200 of pyrethrum flowers equivalent to 1:352,000 pyrethrins gave 44.7% kill while equal dilutions of derris root equivalent to 1:105,000 rotenone gave only 3.4% kill or almost the same as the check. Similar differences are observed by comparing pure rotenone (Table 1) with pyrethrum extracts. While a dilution of 1:88,000 pyrethrins gave 84.5% kill, a dilution of 1:80,000 rotenone gave only 6.4% kill.

TESTS ON APPLE APHIDS. Apple twigs infested with green aphids (*Aphis pomi* DeGe.) and rosy aphids (*Aphis sorbi* Kalt.) were dipped in solutions of various concentrations of rotenone, derris, and pyrethrum extracts. The excess liquid was carefully shaken off and the twigs were transferred to bottles of water and placed on large sheets of white paper, the edges of which were coated with a narrow band of tangle foot. After 24 hours the total number of aphids and those found dead were counted and the per cent kill calculated. Insects found in the tangle foot were considered alive. Checks consisting of 0.50% acetone and water were run simultaneously with the other tests.

TABLE 4. TESTS WITH ROTENONE DISSOLVED IN ACETONE ON APPLE APHIDS

Dilution of rotenone in gms. to cc. water	Total No. of aphids tested	No. of aphids dead after 24 hours	% kill
1:10,000	728	680	93.4
1:20,000	1,112	897	80.6
1:40,000	1,060	809	76.3
1:80,000	729	680	93.4
1:160,000	918	764	83.2
Check (0.50% acetone)	2,213	344	15.5
Check (water)	1,131	133	11.7

TABLE 5. TESTS WITH ACETONE EXTRACT OF DERRIS ROOT CONTAINING ABOUT 3% ROTENONE ON APPLE APHIDS

Dilution of derris in gms. root to cc. water	Approximate dilution of rotenone	Total No. of aphids tested	No. of aphids dead after 24 hours	% kill
1:400	1:13,200	2,055	1,901	93.0
1:800	1:26,400	1,454	1,202	82.1
1:1,600	1:52,800	1,131	884	77.1
1:3,200	1:105,600	1,774	1,296	73.0

TABLE 6. TESTS WITH ACETONE EXTRACT OF PYRETHRUM FLOWERS CONTAINING 0.90% PYRETHRINS ON APPLE APHIDS

Dilution of pyrethrum in gms. flowers to cc. water	Approximate dilution of pyrethrins	Total No. of aphids tested	No. of aphids dead after 24 hours	% kill
1:400	1:44,000	1,214	632	52.0
1:800	1:88,000	1,065	492	46.2
1:1,600	1:176,000	1,741	669	38.4
1:3,200	1:352,000	1,310	564	43.1

The results from these tests, given in Tables 4, 5, and 6, present almost a reverse picture of that obtained from the tests conducted on bees. Both rotenone and derris extract proved much more toxic to aphids than did pyrethrum extract. The lowest concentration of derris extract, namely 1 gm. of roots to 3200 cc. water (Table 5) equivalent approximately to 1:105,600 dilution of rotenone killed more aphids (73.0%) than did the highest concentration of pyrethrum flowers of 1:400 (Table 6). Again, a dilution equivalent to 1:88,000 pyrethrin killed only 46.2% (Table 6) while a dilution of 1:160,000 rotenone (Table 4) gave 83.2% dead aphids.

DISCUSSION. The above presented data are of significance and show beyond a doubt that the toxicity of the active principles derived from derris or cubé roots and the active principles obtained from pyrethrum flowers cannot be correctly evaluated from tests conducted only on one or two insects. The reversible differences in toxicity of rotenone and pyrethrins to aphids and honey bees may also appear in relation to other groups of sucking insects. These results may throw some light upon the causes why so many new insecticides fail to control the insect pests in the dilutions indicated on the label by the proprietor. Efficient control of aphids by a given insecticide does not necessarily mean that thrips, leaf hoppers, red spiders and other sucking insects will also be controlled by it. These results suggest that it is rather a dangerous procedure for the insecticide manufacturer to test his insecticide on one group of insects; assume that other insects will react in the same way, and on the basis of this assumption proceed to label his product as an efficient remedy against all kinds of "bugs." Too often such products fail within a short time after they are placed on the market with heavy financial losses to the uninformed and hasty proprietor.

SUMMARY AND CONCLUSIONS

Extracts of derris root, pyrethrum flowers and pure rotenone were tested as contact poisons on aphids and honey bees. No spreaders were used with any one of these ingredients. All tests were carried out during the summer of 1931 in the laboratory. The results suggest the following conclusions:

1. Derris extract and pure rotenone in high dilution are vastly more toxic to aphids than to honey bees.
2. Pyrethrum extract in high dilutions is more toxic to honey bees than to aphids.

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COMPARISON OF OXIDATION RATES OF LIQUID LIME-SULFUR AND SOLUTIONS OF DRY LIME-SULFUR[1]

By D. E. BULLIS (1), *Department of Agricultural Chemistry, Oregon Agricultural Experiment Station, Corvallis, Oregon*

In the course of some work with commercial dry lime-sulfurs, several experiments on the effect of sludge on the oxidation rate were performed which may be of interest to entomologists and others employing the sulfur scalicides.

Shafer (2) has shown that the insecticidal value of lime sulfur is largely due to its power to absorb oxygen. Abbott (3) and associates, maintain that the presence of sludge in dry lime-sulfur solutions may decrease the efficiency of the spray.

[1]Published as Technical Paper No. 175 with the approval of the Director of the Oregon Agricultural Experiment Station.

It was thought that a comparison of the oxidation rates of liquid lime-sulfur and dry lime-sulfur solutions, both in the presence and absence of sludge, might furnish information pertinent to the relative merits of the two materials.

Since calcium thiosulfate oxidizes very slowly in comparison with the polysulfides, solutions for this study were made up to contain equivalent amounts of calcium polysulfide by weight, regardless of which—trisulfide (CaS_3), tetrasulfide (CaS_4) or pentasulfide (CaS_5)—predominated in the solution. Any difference in behavior of oxidation due to differences in the type of polysulfide present in liquid lime-sulfur and solutions of dry lime-sulfur could then be noted.

The oxidation reactions of the various polysulfides are represented by the equations

$$CaS_3 + 3\,O = CaS_2O_3 + S$$
$$CaS_4 + 3\,O = CaS_2O_3 + 2\,S$$
$$CaS_5 + 3\,O = CaS_2O_3 + 3\,S$$

From these equations it is calculated that one gram of CaS_3, one gram of CaS_4 and one gram of CaS_5 require .35 gram, .29 gram and .24 gram of oxygen respectively for the primary oxidation reaction. It follows that if equal weights of the various polysulfides are oxidized in the same length of time, then the rate of oxygen absorption is greatest for the compound of lowest sulfur content; conversely, if the rate of oxygen absorption is constant then the time required for equal weights of the polysulfides will be greatest for the compound having the lowest sulfur content.

Three methods of measuring the oxidation of the solutions were tried. Two methods proved unsatisfactory and will be only mentioned here. In the first method, Petri dishes of equal area were partly filled with the solution and after a definite interval the solution was filtered and the deposited sulfur weighed. It was found that after a surface film formed, the oxidation was slow and the amounts of sulfur deposited were small and identical for both liquid lime-sulfur and solutions of dry lime-sulfur for a one hour observation period. The second method consisted in the aspiration of a definite volume of air at a definite rate through a definite volume of solution contained in a Nessler tube, with subsequent filtration and weighing of the precipitated sulfur. In no case was a precipitate of sulfur obtained in one hour of aspiration except in three very dilute solutions of liquid lime-sulfur. In concentrations such as are used for dormant spray, no deposit resulted and so the method was discarded.

The third method will be described in more detail since the data to

be presented were obtained by its use. Two Erlenmeyer flasks having an actual capacity of 1150 cc. were fitted with a two-hole rubber stopper in each. One hole of the stopper carried a glass manometer tube of about 2.5 millimeters internal diameter and having each leg about 20 centimeters long. The bottom U bend was filled to a height of 8–10 centimeters with mercury. The other hole of the stopper was plugged with a short piece of glass rod. A lead collar, weighing about two kilograms, was placed around the neck of each flask and the whole immersed in a constant temperature bath to a depth such that the water level was about one centimeter from the top of the flask.

A piece of filter paper, 6.25 centimeters wide by 100 centimeters long was pleated in the short dimension, placed in the flask and arranged in a more or less spiral shape on the bottom of the flask with the aid of a glass rod. A paper of this size has 1250 square centimeters surface area (both sides) and will completely absorb 10 cc. of liquid. This furnished a lime-sulfur film which might be expected to oxidize in a manner similar to that occurring when lime-sulfur is sprayed on trees. After the atmosphere in the flask had reached the temperature of the bath, the stopper was removed from the flask and the glass plug was removed from the stopper. The sample of lime-sulfur solution was distributed over the paper as evenly as possible by means of a pipette, the stopper inserted firmly in the flask and the plug placed in the stopper. In this way insertion of the stopper did not cause a compression of the atmosphere in the flask. The stopper and the plug were paraffined as it was found that the partial vacuum created in the flask by the oxygen absorption caused leakage otherwise. With this set-up, measurement of the difference in mercury level in the manometer was made at two or three minute intervals in the early stages of oxygen absorption; as the absorption rate decreased, the time intervals between measurements were made longer. It is essential that the transfer of the sample and the stoppering of the flask be performed rapidly; it can be done in one minute or less if the apparatus is conveniently arranged. The oxygen in 1150 c.c. of air is sufficient to complete the primary oxidation of about .85 gram of CaS_3, 1.05 grams of CaS_4 or 1.25 grams of CaS_5.

For dormant application, liquid lime-sulfur is diluted sufficiently to contain about 4 per cent of calcium polysulfides. The first solution used in the oxidation work contained 3.90 per cent of calcium polysulfides and all other solutions, after analysis, were diluted to contain the same concentrations, except that used for the data presented in Figure 58.

All oxidations were run in duplicate and to insure against inclusion of any oxidized material, a clean pipette was used for each duplicate.

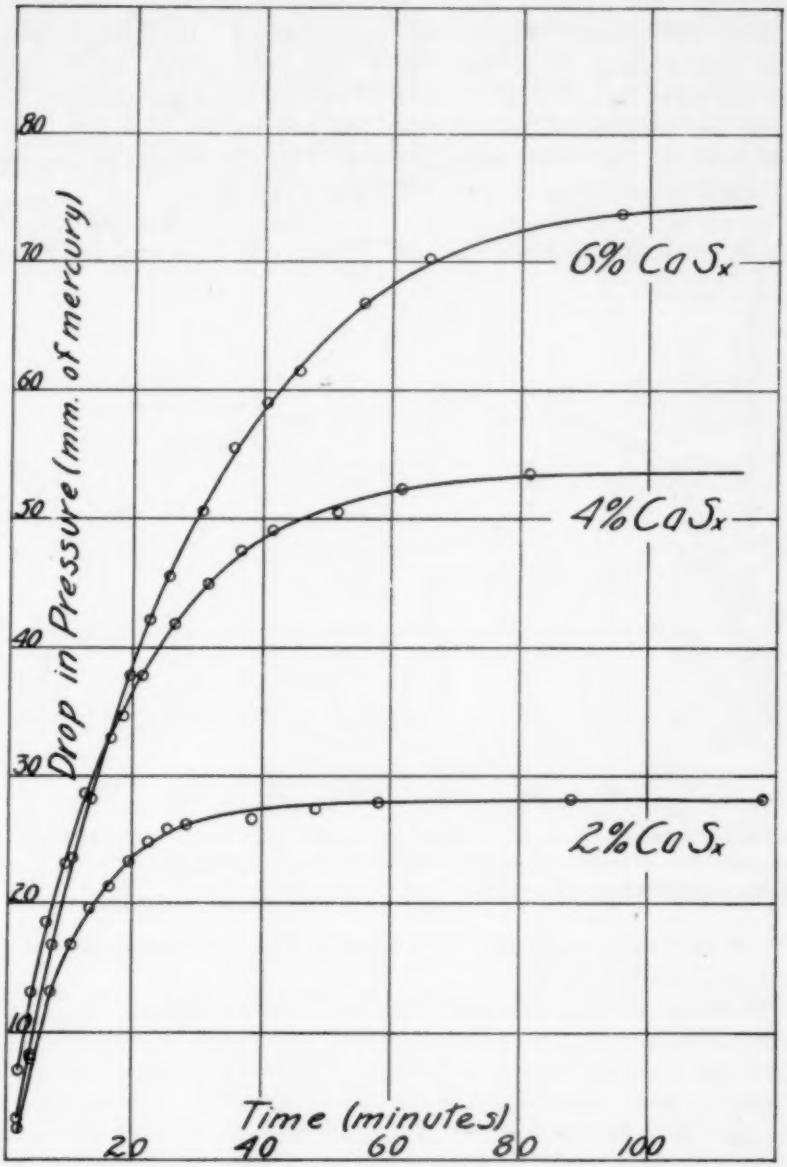

FIG. 58.—Oxidation curves for a liquid lime-sulfur having a monosulfide: sulfide ratio of 1 to 4.70.

Duplicates were found to agree very closely in practically all cases; the few which showed disagreement were repeated. Both liquid lime-sulfur and solutions of dry lime-sulfur were investigated. Oxidations were run before and after the addition of some of the sludge obtained by drying the undissolved residue from the preparation of a dry lime-sulfur solution. All curves were plotted with time in minutes as abscissa and length of mercury column in millimeters as ordinate.

FIGURE 58. The curves of Figure 58 represent the oxidation data of a liquid lime-sulfur in concentrations of 2 per cent, 4 per cent and 6 per

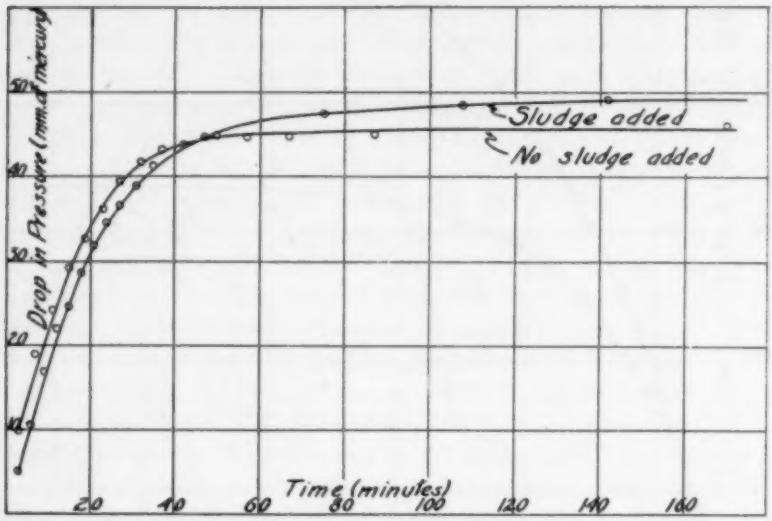

FIG. 59.—Oxidation curves for a liquid lime-sulfur with and without addition of sludge. The solution contained 3.90% of Calcium polysulfides and had a monosulfide: sulfide ratio of 1 to 4.87.

cent of calcium polysulfide. This solution had a monosulfide: sulfide ratio of 1 to 4.70.

The curves show, as one might predict, that the amount of oxygen required is approximately proportional to the polysulfide content of the solutions. They also show that the time required for complete oxidation is approximately proportional to the concentration of the calcium polysulfides. Near the end of the oxidation, decrease in oxygen concentration is responsible for the slight deviation from the proportion just mentioned. In the presence of a constant oxygen concentration, as on a sprayed tree, the break in the curve would be sharp and more of the shape of that representing the two per cent solution of polysulfide.

FIGURE 59. Figure 59 is a comparison of the oxidation rates of a liquid lime-sulfur with and without the addition of .15 gram of sludge to 10 cc. of solution. This solution contained 3.90% of calcium polysulfides and had a monosulfide: sulfide ratio of 1 to 4.87. The sludge was added to the solution and well shaken in an atmosphere of hydrogen before withdrawing the samples. Apparently sludge did not materially affect the rate of oxidation, although the total oxygen absorbed was slightly higher in the samples to which sludge was added.

FIGURE 60. The data for Figure 60 were obtained from a solution prepared by shaking at intervals for three hours, 18 grams of com-

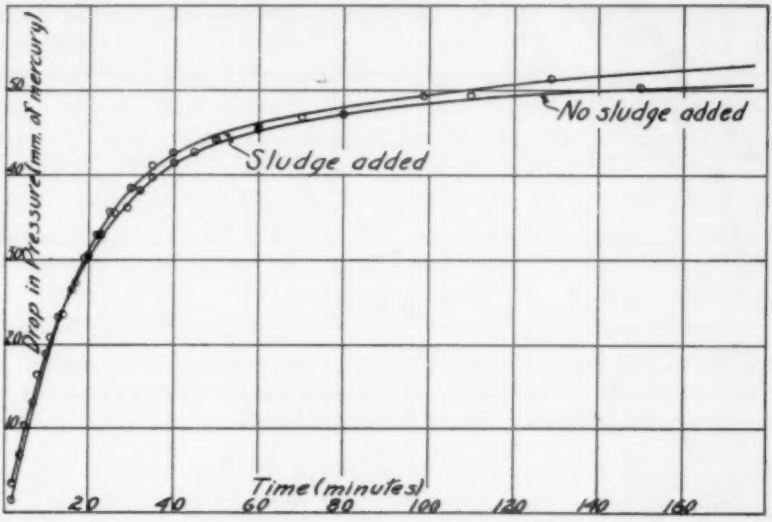

FIG. 60.—Oxidation curves for a dry lime-sulfur solution prepared at room temperature, with and without addition of sludge. The solution contained 3.90% of calcium polysulfides and had a monosulfide: sulfide ratio of 1 to 4.25.

mercial dry lime-sulfur A in 250 cc. volume at room temperature. This solution contained 3.90% of calcium polysulfides and had a monosulfide: sulfide ratio of 1 to 4.25.

FIGURE 61. The solution used for the data in Figure 61 was prepared by heating 15 grams of commercial dry lime-sulfur A in 250 cc. volume on a water bath for 45 minutes. This solution contained 3.90% of calcium polysulfides and had a monosulfide:sulfide ratio of 1 to 4.42. The difference in the monosulfide: sulfide ratio of this solution and the one used for the data of Figure 60 indicates a difference in the type of polysulfides present, but the curves are practically identical with the

exception of the slight rise near the end of the oxidation in those samples to which sludge was added.

A careful consideration of Figures 59, 60, and 61 fails to provide any basis for the assumption that there is any difference in the oxidation

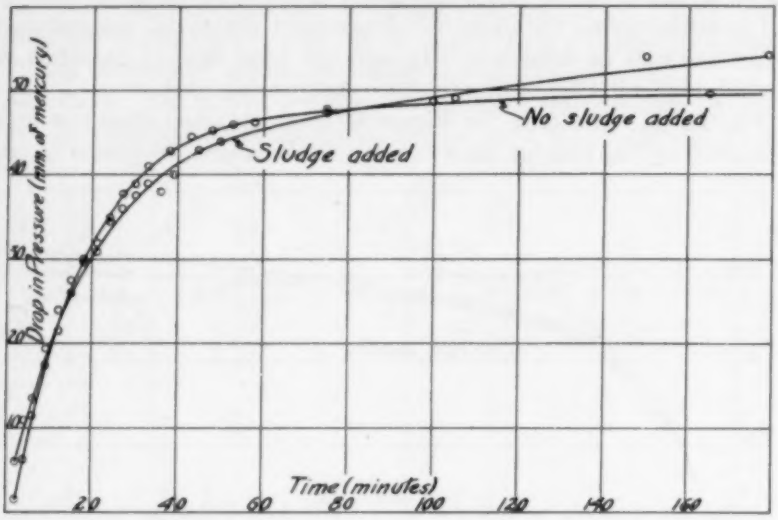

FIG. 61.—Oxidation curves for a dry lime-sulfur solution prepared by heating, with and without addition of sludge. The solution contained 3.90% of calcium polysulfides and had a monosulfide: sulfide ratio of 1 to 4.42.

rates of liquid lime-sulfur and solutions of dry lime-sulfur of the same calcium polysulfide concentration. The presence of sludge has a very slight, if any, effect on the oxidation rate of such solutions.

SUMMARY

The rate of oxidation of liquid lime-sulfur and dry lime-sulfur solutions is the same at equal concentrations of calcium polysulfide. Sludge does not materially affect the rate of oxidation.

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A VISUAL METHOD OF COMPARING TOXICITY OF CONTACT DUSTS

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ABSTRACT

A method of testing comparative toxicity of contact dusts is described in which the tracks made by dusted insects in dust films are used as indicators of toxicity.

Except as a final check under field conditions, the writer has found the dusting of infested plants to be an unsatisfactory method of comparing the toxicity of contact dusts. The principal objection is that it is difficult to dust a series of plants so as to have the treatments thorough and uniform.

To avoid this difficulty in testing a large number of contact dusts to determine toxicity and loss of toxicity over a period of months under various storage conditions, the writer has devised the following method: A cylindrical glass jar of about three gallons capacity has been fitted with a thick pasteboard lid. The lid is hinged to the jar with adhesive tape on one side. On the other side of the jar, a gum band, taped to the jar, fastens over a cork glued to the lid and holds it in position. A hole about three fourths inch in diameter is cut in the lid and fitted with a cork. See Fig. A, Plate 29.

In testing a dust, a quantity is used sufficient to fill the jar with a heavy fog when puffed in with a dust atomizer. One half gram of dust gives satisfactory results. The test insects, usually five or ten in number, are placed in the lower half of a petrie dish. The petrie dish half with the insects is then placed in the jar which rests on its side, the petrie dish being set just inside the jar so that it touches the lid when the lid is closed. If the petrie dish is placed in towards the bottom of the jar, the dust blast may blow some of the insects out of the petrie dish and the dish will also receive a heavy uneven deposit of dust. After the lid is closed and the cork removed, the dust is blown in and the cork replaced. The jar is left closed for two minutes to allow the dust to settle, after which the petrie dish is removed and observations made at intervals of one minute until all insects are moribund. Observations are also made through the glass jar before the petrie dish is removed since the more toxic dusts are effective in less than one minute. To compensate for the small number of insects in each test, tests are repeated several times.

While making these tests it was observed that the insects in moving about in the dish recorded their movements in the film of dust. In the case of an ineffective dust, the insects would kick up the entire dust

layer while with more toxic dusts, well defined tracks were left which became shorter and shorter as the toxicity increased. Fig. B of Plate 29 illustrates this point. Three dust treatments are shown in which five first instar squash bug nymphs were used as test insects. The minutes required for the insects in each treatment to become moribund are shown by the numbers over the petrie dishes. Since the amount of dust displacement is inversely proportional to the toxicity, it occurred to the writer that instead of watching each treatment and recording the effects, that for some purposes, the records left in the dust by the insects would be sufficient for comparison. This has effected a considerable saving of time since it is possible to proceed rapidly with a large number of treatments and later on at one's convenience examine the treatments for effectiveness.

In using this visual method it is necessary to select an insect which is able under ordinary conditions to traverse a dust film on glass. Many species of aphids are heavy bodied and sluggish and will easily become overturned and unable to right themselves. The pea aphid, *Illinoia pisi*, makes an excellent test insect. It is active and hard to kill. Various Hemipterous nymphs are quite suitable.

One objection to the method lies in the use of petrie dishes. The bottoms are uneven and the insects which naturally tend to collect at the edge of the dish are inclined to the edge by the slope of the glass. To avoid this difficulty flat bottomed glass dishes may be used.

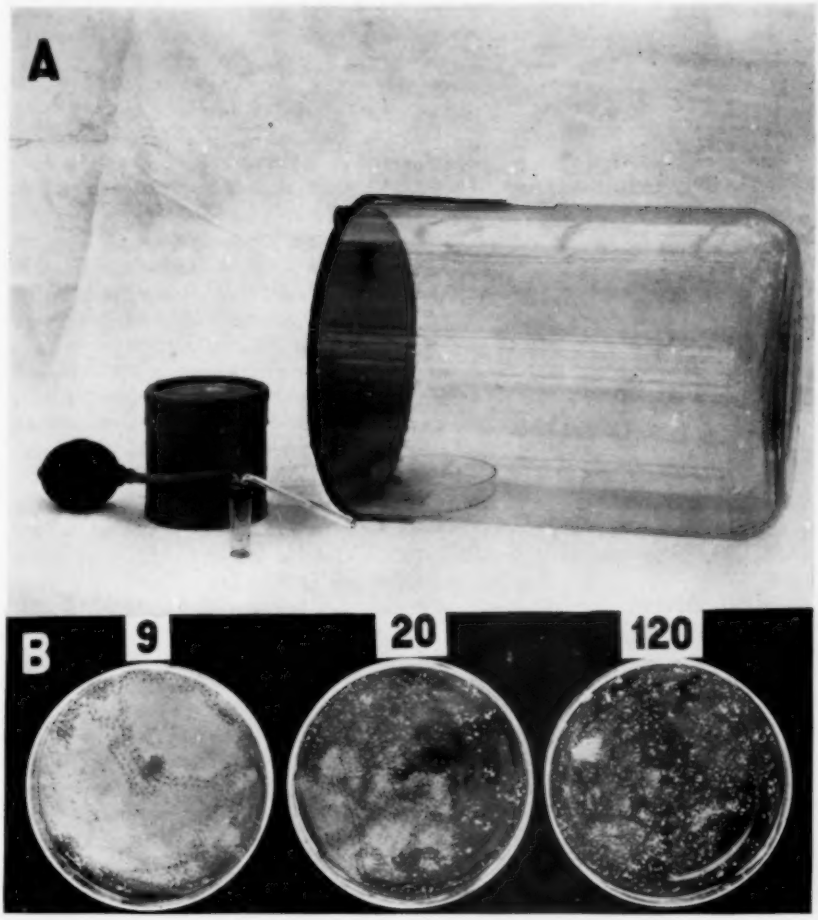
Scientific Notes

Privet Thrips, *Dendrothrips ornatus* Jabl. This is another introduced insect concerning which little has been recorded, the only notice which has come to attention being a brief account in Andrew Wilson's "Insects and Their Control" published first in 1929 and revised in 1931. Specimens of this insect were received from Mamaroneck, N. Y. early in July and were subsequently found at Stamford and Fairfield, Conn. and Melrose Highlands and Ipswich, Mass. In no case was there serious damage. This thrips is presumably somewhat generally distributed.

E. P. FELT

An Early Quarantine in Puerto Rico. In a Memoria prepared by Sr. Cayetano Coll y Tosti published in the Boletin Historico de Puerto Rico 1:303, 1914 he copies the Cedula de Gracia (Decree of Grace) of Spain of August 10, 1815, Article 31 of which refers to the establishment of a quarantine against ants. A translation of this is as follows:

"Likewise is the said governor [of Puerto Rico] admonished that he exercise the greatest vigilance that he avoid the introduction of the plague of ants into the Island which has caused so much damage in some of the Antilles, causing to be examined the individual baggage of all Colonists who may enter Puerto Rico from the said Islands;



A. Equipment used in testing comparative toxicity of contact dusts. B. Petrie dishes showing tracks made in various contact dust films. The numbers represent minutes elapsing between treatment and cessation of movement.

and it being supposed that the inhabitants are those who are interested in this matter they will propose to the Governor two satisfactory and active individuals to inspect all ships and to see to the fulfillment of this measure."

In a foot-note by Coll y Tosti he states that this refers to the "bibijagua." This is the Cuban leaf-cutting ant, *Atta insularis* Guerin. The above is undoubtedly the earliest quarantine in Puerto Rico established against an injurious insect.

M. D. LEONARD, *Chief, Division of Entomology,*
Insular Experiment Station at Rio Piedras, Puerto Rico.

Injury by a Japanese weevil, *Pseudocneorrhinus setosus* Roelofs. This weevil was first collected in New Haven, Conn., in 1920 and more material was gathered in 1921 and 1922 in the same locality where the Asiatic beetle, *Anomala orientalis*, was discovered. Some difficulty was experienced in obtaining an identification, but in 1923 it was identified by Dr. G. A. K. Marshall of the British Museum. An attempt was made to ascertain its food plants and some of the weevils were found feeding upon burr marigold, *Bidens* sp. A note about the insect was published in the report of the Station for 1923, page 313, with illustrations of the beetle on Plate XXIV,e. On June 8, 1932, I received some specimens from West Haven following a telephone conversation, and they proved to be this weevil. I visited the place and saw the weevils at work. They were feeding upon the leaves of Japanese barberry, California privet, lilac and the new tips of hemlock, and had already caused considerable injury. Two hemlocks had been killed and removed. A privet hedge perhaps 50 feet in length and a row of Japanese barberry along the house foundation were stripped last year according to the owner. Apparently the beetles have no wings, a fact that will not favor the rapid spread of the insect in this country. An attempt will be made to learn something about its life history and larval habits.

W. E. BRITTON, *Agricultural Experiment Station, New Haven, Conn.*

First Record of *Hypera postica* **Gyll. in the San Joaquin Valley, California.** The discovery of the alfalfa weevil in the important alfalfa area near Tracy, California, on May 12, 1932, came as the result of a chance sweeping with an insect net. The writer had spent the day investigating the effects of an infestation of aphids upon range plants on the hills near by and was hurrying to Sacramento in the late afternoon when it occurred to him to make at least one sweeping in alfalfa to determine the abundance of the black-striped army worm. The first fifty sweeps of the net produced one adult of *Hypera postica* Gyll. Several additional sweepings did not result in further findings. Sweepings in several fields in the same locality two days later yielded two adults and several nearly grown larvae of the weevil.

Subsequently, the State agricultural authorities conducted a survey that resulted in the finding of infestations in portions of the following counties: San Joaquin, Stanislaus, Alameda, Contra Costa, and Santa Clara. In view of this fact the California Director of Agriculture announced a conference which was held in San Francisco on May 25, where the situation was thoroughly discussed. Although it was considered inadvisable to attempt eradication, it seemed that the control of the alfalfa weevil in its new environment should not be difficult.

R. A. BLANCHARD, *Division of Cereal and Forage Insects,*
Bureau of Entomology, U. S. Department of Agriculture.

Apple Leaf Curling Midge, *Dasyneura mali* Kieffer. Specimens of apple leaves rolled by midge larvae and provisionally identified as this species, were received the latter part of June through Prof. W. D. Whitcomb of the Massachusetts State College Experiment Station, Waltham, from Dr. J. L. Goodale, Ipswich, Mass., accompanied by the statement that the insect was somewhat prevalent in an orchard. It had not caused serious damage, although it was known to be present in 1929 and may have been brought into the country with French stock about 1912.

The terminal leaves on some four or five inches of the young growth had the margins inrolled, the tissues being somewhat thickened and showing a distinctly reddish-brown, somewhat mottled coloring. A number of white or yellowish-orange larvae were found within the leaf rolls. Eggs, young and full grown larvae were also observed July 21 under conditions suggesting continuous breeding for at least four weeks. The height of breeding appeared to be June 20. The midge exhibited a marked preference for Delicious apple trees when first observed though such is not the case this year.

A brief, general description of the insect and its work is given by Dr. H. F. Barnes in the Journal of the Southeastern Agricultural College, Wye, Kent, No. 24, page 106–107, 1927. The European history indicates no serious outbreak in the Old World. Dr. Barnes states that it has been found in several English localities and has been recorded from France, Germany and Italy. This is apparently the first record of the occurrence of any such insect in this country.

E. P. FELT

Reduction of White Grub Injury by Bordeaux Mixture. In October 1930 while checking on the yield of potatoes from sprayed and unsprayed plots, the writer was impressed by the large percentage of white grub injury, especially on potatoes from unsprayed plots. The potatoes from the unsprayed rows were so noticeably injured by grubs as compared with the potatoes from the Bordeaux sprayed rows, that counts were made of a couple of crates of potatoes from each plot.

The greater portion of the field was sprayed with Bordeaux 4–4–50. Four check rows were left near the lower side of the field, four in the middle of the field and four near the upper side of the field. Near the check rows were several rows which received arsenate of lead as in the Bordeaux plots, but no Bordeaux.

Counts were made of potatoes from the different locations as follows:

Treatment	% of white grub injury		
	Lower field	Middle field	Upper field
Bord. 4–4–50 and ars. of lead 2 lbs. to 50 gals. in 1st three applications	7	16.2	19.1
Ars. of lead 2 lbs. to 50 gals. in 1st three applications	11.5	25	41
Check	10	43.3	43.2

Further observations were made on sprayed and unsprayed potatoes in 1931. Very little grub injury occurred in 1931. Counts at harvest time, however, showed a slight difference in favor of Bordeaux. Two hundred fifty potatoes from the Bordeaux plot showed no grub injury while out of two hundred fifty potatoes from the check plot, four were injured by grubs.

J. R. STEAR,
Experiment Farm Koppers Research Corp., Ligonier, Pa.

Disposition of Peach Drops Infested with *Conotrachelus nenuphar* Larvae by Submergence in Water.—The collection of peach drops from southern orchards is a popular supplementary measure for the control of the plum curculio. Burying has been recommended as a method to make peach drops harmless, but the results of recent experiments show that burying is not a safe method of disposal.[1],[2] It then occurred to the writers that submergence in water may make peach drops harmless, and consequently an experiment was conducted during the season of 1931 to determine if that method is effective and practical.

One bushel of peach drops infested with *C. nenuphar* larvae was placed in each of seven burlap bags on May 11 and completely submerged in a flowing stream after the tops of the bags had been tied with rope. The bags were removed from the water at intervals during the four weeks following their submergence to determine the time required to drown the larvae. A submergence period of 28 days was required to make infested peach drops harmless; 98.3 per cent of the larvae were drowned from that period of submergence. The mortality of *C. nenuphar* larvae from drops which had been submerged in water for a period of 18 days was only 48.3 per cent. All of the larvae appeared lifeless when removed from the drops which had been submerged, but the live ones revived within thirty minutes.

On May 30 twenty mature larvae were placed on soil in a cage 18 hours after they were removed from drops which had been submerged in water for 18 days. Fourteen entered within six hours. One *C. nenuphar* adult emerged from this cage on each of the following days: June 20, 24, 25, and 26. Of sixty larvae removed from drops which had been submerged in water for 28 days only one revived. That individual was placed on soil in a cage 18 hours after it was removed and it entered during the night but no adult developed from it.

A few southern growers dispose of infested peach drops by dumping them into a flowing stream or river. In order to observe the movement of drops dumped into moving water and the effect on curculio larvae, one bushel of infested drops was dumped into a flowing stream on May 12. The drops which were shriveled sank immediately, but the others floated. Twenty-four hours later some of the drops were observed floating in quiet places near where they were dumped, and some were lying on the shore where they had been splashed out by vehicles fording the stream. *C. nenuphar* larvae removed from drops which had been floating in the stream for 48 hours were inactive and appeared dead at first but became very active as soon as they were dry and warm.

Peach drops infested with *C. nenuphar* larvae can be made harmless by placing them in burlap bags and completely submerging in water for at least four weeks. Dumping loose drops in a stream or river is not considered a safe method of disposal on account of the danger of larvae escaping from those that float and come to rest on the bank of the stream when water recedes. It is a question, however, whether or not the places where drops are left on the shores by receding waters would be suitable for completion of the metamorphosis of curculio larvae.

OLIVER I. SNAPP and J. R. THOMSON, *U. S. Peach Insect Laboratory,*
Fort Valley, Georgia

[1]Snapp, Oliver I., and Thomson, J. R. Burying Peach Drops to Prevent the Escape of Plum Curculio Adults. J. Econ. Entom. 24:559–560. 1931.

[2]Snapp, Oliver I., and Thomson, J. R. A Second Report on Burying Peach Drops To Prevent the Escape of Plum Curculio Adults. J. Econ.Entom. 25: 415–416. 1932.

Temperature as a Measure of an Insect Population. "The heating of grain may be caused either by a high moisture content, or by the presence of insects. Peas infested with weevils have been known to heat to as high as 103°F. when the normal temperature was 58°F. Wheat stored in farmers' bins and well infested with the rice weevil and flat grain beetle have been found heating to 109°F. when the normal temperature was 27° F." (Back & Cotton: U.S.D.A. Farmers Bul. 1483, p.28)

"The heating of the grain in the bin is sometimes the first indication that the average grower has that his grain is infested" [with the Angoumois grain moth]. (U.S.D.A. Farmers Bul. 1156, p. 5)

This heating of the grain is an important factor in the mass production of the Angoumois grain moth. Such heat is the result of insect action and is known as the "heat of infestation." (J. E. E. Vol. 23, p. 839).

When infested grain is fumigated, the heat of infestation (H. I.) disappears, proving that it is a concomitant of the insect population. The writer took advantage of this fact to register the building up of the Angoumois grain moth population used in *Trichogramma* production work. When the H. I. exceeds a temperature of about 85°F., the insect population ceases to build up; and as the H. I. increases, reproduction decreases. To maintain maximum moth production the grain must be artificially cooled.

"It is not strictly true that the body temperature of poikilothermic animals ——is always the same as the temperature of the surrounding medium. During the time of activity, a certain amount of energy is continually being transformed into heat in the body; and as long as the rate of radiation from the body is less than the rate of production of heat within the body, it follows that the body temperature will be somewhat above that of the surrounding medium." (Chapman, Animal Ecology, p. 43).

The H. I. may be due to the direct transference of the body heat to the grain; or to the heat produced by mandibular friction in eating. Whatever the method by which the H. I. is built up, it is at least a rough means of comparing grain insect populations when the air temperatures surrounding the containers are the same.

STANLEY E. FLANDERS, *Riverside, California*

Thrips Injury to Citrus and Rose in Puerto Rico. Since coming to Puerto Rico two and a half years ago, the writer has repeatedly observed a small to moderate percentage of grapefruits and oranges in the packing houses in the principal citrus growing sections scarred with typical thrips marks. The growers seemed to be unfamiliar with this type of blemish and, upon being questioned, always attributed it to some other cause.

I had also often observed thrips in greater or less numbers in the blossoms thruout the citrus belt but had never sent specimens to a specialist for determination. Following an unusually prolonged dry spell there was a considerable general bloom in April 1932 and thrips were fairly common in the blossoms in several sections visited. Specimens were collected from grapefruit and citron and sent to both Prof. J. D. Hood of the University of Rochester and Prof. J. R. Watson of the Florida Agricultural Experiment Station for determination. Prof. Watson writes me under date of June 29, 1932 that "the common black thrips on citrus blossoms in the West Indian Islands seems to be *Frankliniella insularis* Franklin. The yellow one is chiefly *F. cubensis* Hood." The latter seemed to be somewhat more abundant in the blossoms than the former during the spring of 1932. Professor Watson, however,

has recently determined thrips from grapefruit blossoms from Palo Seco, April 4, collected by A. S. Mills and from Vega Alta, April 15, 1932, collected by C. G. Anderson, both of the U. S. Plant Quarantine and Control Administration Office at San Juan as *Frankliniella insularis* Franklin and *F. difficilis* Hood. The latter species has apparently not before been reported from Puerto Rico.

W. V. Tower has apparently been the only one to ever mention thrips injury to citrus or the presence of these insects in the blossoms in Puerto Rico. In his Report of the Entomologist of the Puerto Rico Agricultural Experiment Station (Mayagüez) for 1919 on pages 24–25, 1920 he records having attempted to demonstrate thrips injury by tagging a number of grapefruit blossoms each containing more than 25 thrips. Altho no thrips injury had appeared on the fruits under observation up until the time his report was closed for publication, he states that thrips marks were later observed in groves of cultivated oranges on the North Coast and on wild oranges in packing houses in Mayagüez. Apparently the species involved seem not to have been determined.

Under date of June 1, 1932 Mr. Arturo Riollano, the Agricultural Agent for Vieques Island, P. R., sent for determination numerous specimens of a black thrips which Prof. Watson has determined as *Frankliniella insularis* Franklin. It was stated that great damage was being done to rose bushes, especially on five different properties, but the trouble was more or less general at that time. Similar injury had not before been observed on Vieques but Mr. Riollano stated that it had been previously noted in Mayagüez as well as in several other towns but had never been reported. Buds attacked never open or the flowers are totally spoiled, the withered ones when examined are literally full of thrips, especially at the base of the petals. Some gardens in Vieques were 100 per cent infested and not a sound rose could be found. Canna blooms were also being attacked but suffered less damage.

M. D. LEONARD, *Chief, Division of Entomology, Insular Experiment Station at Rio Piedras, Puerto Rico.*

Hibernation of the Striped Cucumber Beetle, *Diabrotica vittata* (Fab.), and Records of Spring Food Plants. Observations on the hibernation quarters of the striped cucumber beetle were made during the winter and spring of 1931–32 in the vicinity of Urbana, Illinois. Striped cucumber beetles were found hibernating in a woodland of approximately sixty acres in extent, on the soil surface, under heavy leaf covering in the midst of clumps of saplings, away from the bases of trees, at distances of from forty to one hundred and twenty yards in from the edge of the woods, February 18, 22, 25, 29, and March 16. The nearest cucurbits had been just across the road from the woods.

March 15, six beetles were found under loose bark on the lower side of a decaying tree which had blown down in a storm. This situation was in a grove of trees directly west of an old melon patch.

March 17, three other beetles were discovered hibernating in a woodland, on the soil surface, under leaf cover, under wide strips of bark lying close by fallen trees.

March 29 and April 5, eight beetles were observed clinging to the undersides of rotten pieces of wood, lying in tangles of brush and vines close to the bases of trees in the same woodland. Six beetles were found clinging to one of the pieces.

April 1, three beetles were taken separately at the bases of clumps of grass along a neglected fence row.

April 18 and 19, three striped cucumber beetles were seen crawling over leaves on the ground in the woodland mentioned above. The temperatures those two days reached 65°F. and 68°F. respectively.

April 20, at a temperature of 72°F., beetles were found out of hibernation for the first time, in the same woodland. Forty-five beetles were seen. All were on fetid buckeye and many were feeding.

Beetles were observed for the first time along streams April 28 when they were taken feeding on the staminate blossoms of black willow.

Food plants of beetles in the woodlands were fetid buckeye foliage and blossoms, Crataegus blossoms, giant ragweed foliage, Aster foliage, wild geranium blossoms, Hydrophyllum blossoms, and several undetermined compositae.

Food plants of beetles feeding along streams and in bottom lands were staminate blossoms of black willow, wild plum blossoms, giant ragweed foliage, goldenrod foliage, and seedling apple blossoms.

Striped cucumber beetles were very abundant in woodlands from April 20 to May 8. They were abundant along streams and in bottom lands after May 3.

The first mating pair of beetles was taken May 4 on fetid buckeye in the woodland.

May 20, beetles were first found on cultivated cucurbits when they descended in hordes on two patches of transplanted cucumbers. However, beetles were found a week before in a country garden just thirty yards south of a wooded stream bank where beetles were abundant on compositae.

PAUL O. RITCHER, *Urbana, Illinois*

Permanent Preservation of Biological Specimens in Gelatin.[1] The method of mounting fragile biological specimens described here seems superior to the practice of mounting them in alcohol and sealing in glass tubes. The completed gelatin mounts are surprisingly rugged, being able to withstand dropping several feet with little danger of breakage, and no damage to the specimen. There need be no fragile tip of glass left in sealing the tubes. No movement of the specimen can take place in the stiffened gelatin, because the formalin changes it to a derived protein which will not liquify after having set firmly. Orientation of the specimen and label must be done before gellation. More than one specimen may conveniently be mounted in one tube. There is no formation of white flocculent debris which collects on objects preserved in alcohol or formalin. The person who seals the tubes is in no danger from explosion, as is the case in sealing tubes filled with alcohol.

MOUNTING MEDIA. The gelatin must be highly refined. "Difco Standardized Bacto Gelatin" or "Swifts Purified Gelatin" is satisfactory, giving a jelly which is perfectly clear and remains so indefinitely.

10 grams of purified gelatin
36 drops of formalin (40%)
100 grams of water.

Heat the water to boiling, add the gelatin and allow to dissolve thoroughly. Just before pouring into the tubes, add the formalin.

It is essential to the permanency of the mounts that the specimens be properly killed and fixed before being put into the gelatin. Soft bodied insects and other tender animals should be killed by warming in water until death rigor has occurred.

[1]The foundation of this method was reported by Mr. H. C. Lewis in volume 22 page 980 of this journal. The present note is a contribution to technique rather than a total innovation.

In order that the hypodermis may not act as a dializing bag, and either puff out or shrivel, the tissues must be made isotonic with the gelatin medium. After fixing the specimens in Kahles fixative for several hours, soak them in tap water for at least twelve hours to remove all traces of the alcohol remaining from the fixative. Kahles fixative is:

95% alcohol	15 parts
40% formalin	6 parts
Glacial acetic acid	2 parts
Distilled water	30 parts

Better results are had with fresh fixative.

Vaccine tubes or test tubes of other sizes make good containers in which to mount the larger insects. A method of making cheaper tubes for small mounts follows:

Make sections of soft glass tubing by melting apart a long piece into short lengths, twice as long as desired to use. The resulting pieces are to be filed and broken in the middle to make two vials. In order to have nicely rounded ends, the long tube must be sealed at both ends and then severed at the proper places in a very hot flame. When the glass becomes very soft, draw the pieces apart quickly without removing them from the flame. By cautiously heating the severed ends before they cool, the air sealed within can be expanded just enough to round out the soft glass and form a smooth end, like that of a test-tube. A blast lamp fed coal gas and pure oxygen gives the necessary high temperature for working the glass.

It is convenient to fill the tubes from a heated funnel through a pinch clamp and slender pipette so that no gelatin will be spilled on the sides of the tube. Orient the specimen within the tube and let media flow in to cover it. After the gelatin has set, the tubes may be sealed in the same manner as described above for making them. The seal should be made about five centimeters or more above the media to prevent scorching.

CRAIG W. EAGLESON,
Ohio State University

JOURNAL OF ECONOMIC ENTOMOLOGY

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The editors will thankfully receive news matter and other items likely to be of interest to our readers. Papers will be published as far as possible in the order of reception, except that papers of reasonable length may be accepted in the discretion of the editor for early publication at $3.00 per page. There is a charge of $3.00 per page for all matter in excess of six printed pages, a part page counting as a full page, this limit not including acceptance illustrations. Photo-engravings may be obtained by authors at cost.

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A. A. A. S. Winter meetings: 1932-33 Atlantic City; 1933-34 Boston; 1934-35 Pittsburgh; Summer meetings: 1932 Syracuse, 1933 Chicago, 1934 San Francisco.

The recently announced revocation of the domestic European corn borer quarantine should not be allowed to pass without comment. It is an important step justified, in the opinion of Secretary of Agriculture Hyde, by the certainty that Federal funds for the enforcement of this quarantine will be inadequate. There has been a cut of practically sixty-six per cent in the appropriation for this purpose. It certainly is not wise to maintain an activity hopelessly restricted by insufficient funds, and the Secretary is to be commended, under the circumstances, upon taking such action.

It is interesting to note that the quarantine applied to thirteen States, and its enforcement necessitated supervision along an extended border. Some question the utility of certain quarantines, and even those who urge quarantine control most strongly admit that all that can be expected is a slowing up of the normal spread and the elimination, in a measure, of the probability of distant infestations resulting from commercial activities. Certain students of the larger quarantine problems seriously question the actual value of such slowing up and believe that in the long run the occasional distant infestation is speedily overtaken by a normal spread which is practically uncontrollable. The sentiment for quarantine enforcement is usually more general in the territory outside of the infested area, and while, in some cases, self interest may be the dominant factor, it is only fair to believe that a portion of this difference is due to diverse viewpoints. The principal corn growing States of the Middle West are disturbed by this action of the Secretary and according to press dispatches are working on cooperative measures

Plate 30

Anthony Spuler

to protect themselves so far as may be possible. These will probably be in force before this is published. Fortunately, the movement of corn and plant products likely to be infested is mostly eastward and as a consequence an embargo, if one were declared, would be much less serious than if the trend of these shipments were in the opposite direction.

Granting that the revocation of the European corn borer quarantine remains effective, there will be an opportunity to compare the spread of this insect unchecked by quarantine with its dissemination in earlier years. The psychological effect is also an important one. It is possible that those in the uninfested areas may come to look at this pest, now that quarantine has been abolished, with somewhat less apprehension than has been the case in previous years. Experience has shown that severe damage by this insect is not general but limited by various factors. It is to be hoped that none will take advantage of the situation and carelessly or willfully contribute to a rapid spread of the borer into uninfested areas. There is no escaping the fact that the spread of the European corn borer is inevitable. The practical question is,—was the Federal quarantine really worth while and if so, is it advisable to seek its reestablishment at the earliest possible date?

Obituary

ANTHONY SPULER

With the death of Anthony Spuler, who together with Mrs. Spuler, was accidentally drowned in Lake Wenatchee, May 30, 1932, economic entomology has suffered a heavy loss. Less than one hundred fifty feet from shore, the motor of their small boat stopped suddenly; the boat worked down into the trough and capsized. Spuler's body was not recovered until the next morning, when it was found by his colleague, Prof. F. L. Overley, whose wife had accompanied the Spulers on the fateful trip.

Anthony Spuler was born in Genesee, Idaho, December 19, 1889. He came to the State College of Washington as a student in 1909, majoring in entomology under Dr. A. L. Melander, but did not complete his work until 1917. At one time he had actually given up college work and was engaged in farming in Montana, but was encouraged by Doctor Melander to return and complete his course. He received his master's degree from the same institution in 1919.

As a student of Melander's, Spuler's first activity was in systematic entomology, especially the family *Borboridae*. As assistant entomologist of the Experiment Station, his work dealt later with the development

of a poison apple bait now in general use in the Pacific Northwest as the best known control means for strawberry weevils. Working with E. L. Green, representing the Division of Chemistry, a foundation was laid for further intensive investigation of oil sprays.

In 1926, Spuler was detailed to Wenatchee, Washington, in response to urgent requests from the fruit industry for more detailed investigations on codling moth control. Already well trained, he found it necessary to study the whole problem in all its phases, and for several years, working practically alone in the field, his efforts commanded little attention. When recognition finally came, the whole horticultural industry of the Pacific Northwest came to depend on the results of his investigations.

In 1926, Spuler brought out the idea that spray dates could be more adequately determined by the use of moth traps. Until about this time, orchardists generally maintained what was known as a "ten-day schedule," in order to keep apples protected from worm attack, especially during the fore part of the season. It was his idea that the various cover sprays could be far better timed if the application was made with particular reference to the peaks of emergence of the codling moth from week to week during the season.

As time went on, he became interested in various combination sprays, especially those in which lead arsenate and mineral oil were used. Later the subject of certain of the non-arsenicals occupied his time, and more recently he had been concerned with the comparative value of various lead arsenates. At the time of his death, he was working in an attempt to outline specifications for fish oils with special reference to their use with lead arsenate. He was cut off at a time when he was really at the height of his scientific career.

A clear thinker, with a keen, analytical mind, he had an ability to sense principles from a mass of data that was nothing short of remarkable. Years of experience in the field of insect control, coupled with boundless energy and determination, and above all honesty, gained for him an outstanding position among economic entomologists. His work has made a lasting impression.

His standing in the Pacific Northwest may perhaps best be illustrated by the following excerpt from the editorial page of the "Wenatchee Daily World:"

"The death of Mr. and Mrs. Anthony Spuler who were drowned in Lake Wenatchee Monday, is a distinct loss to the state of Washington and to the fruit industry particularly. Spuler's work in connection with the orchard laboratory here constitutes one of the most notable contribu-

tions to horticulture that have been made during the past decade. He worked out the method of observing the brood periods and the development of the codling moth through the use of the moth trap. This method not only fixes the proper date for spraying, but it aids materially in controlling the spread of the pest. However, this was only one of the projects upon which Spuler has been working for the past few years.

"Spuler was in the midst of vital experiments and studies that would have meant much to the fruit growers of the state had he lived to complete them. The world can ill afford to lose so useful a man as Anthony Spuler who was cut down while still at the very height of his activity. He was indispensable to horticulture, and his death constitutes a well nigh irreparable loss."

Mr. Spuler was a member of the Washington State College chapters of the honorary societies Phi Kappa Phi and Sigma Xi.

R. L. WEBSTER

Current Notes

Dr. C. W. Johnson, Curator of Insects in the Boston Society of Natural History and a widely known Dipterist, died at his home in Brookline July 19 after an illness of some three weeks.

Dr. S. A. Graham, Professor of Entomology, University of Michigan has been appointed Visiting Professor of Entomology at Ohio State University during the summer term and is conducting a course in insect ecology.

Professor Herbert Osborn and Mrs. Osborn sailed July 1 from New York City to attend the International Entomological Congress at Paris. They expect to spend the greater part of July and August in Europe.

Mr. Gonzalo Merino in charge of the entomology work at Manila, P.I. and who is at present a graduate student in Entomology at Ohio State University sailed for Paris on July 1 to attend the International Congress.

On May 12, the North Dakota Department of Entomology had a visit from Dr. J. R. Parker and Mr. R. L. Shotwell of the Bureau of Entomology and from Dr. J. C. Faure of Pretoria University, Union of South Africa. They were looking into the grasshopper situation.

F. C. Bishopp, Bureau of Entomology in charge of insects affecting man and domestic animals, Harry L. Gui, Assistant Entomologist, the Ohio Experiment Station and E. P. Breakey, of the Ohio Biological Survey received the degree of Doctor of Philosophy at the Ohio State University in June.

During May, Mr. W. G. Bruce, Assistant Entomologist, Division of Insects Affecting Man and Animals, resumed fly trapping experiments and investigations on the cattle grub at the State College Station, Fargo, N. D. He was located at the Bureau Laboratory, Dallas, Texas, during the past winter.

The grasshopper situation over a large section of North Dakota has been causing the people no small amount of worry according to Mr. J. A. Munro, State Entomologist of North Dakota. The heavy rains of May 25 and 26 which were fairly general over this area gave some assistance in the fight against the pest.

On May 6 and 7 G. V. B. Herford, Entomologist, Royal College of Science and Technology, London, visited the Richmond laboratory Bureau of Entomology and discussed the problem of tobacco fumigation on the docks and in the warehouses of London.

Perez Simmons, Bureau of Entomology, Fresno, Calif., attended the Dried Fruit Conference at the University of California on May 6 and gave an informal talk on "New developments in investigations of dried fruit insect control."

T. Bainbrigge Fletcher, Entomologist of the Imperial Government of India at Pusa, and a well known Lepidopterist visited the San Antonio, Tex., laboratory on May 27. He studied the Lepidopterous fauna in that region before leaving for the International Entomological Congress in Paris in July.

Dr. P. N. Annand, Entomologist, in charge of the field laboratory at Twin Falls, Idaho, has been transferred to Washington, D. C., to act as assistant to W. H. White, division leader, in the direction of the work of the Division of Truck Crop and Garden Insect Investigations, of the Bureau of Entomology. Doctor Annand is particularly well fitted for this assignment, as he very successfully directed the investigations of the sugar-beet leafhopper and is familiar with the problems relating to truck crop insects in the West.

The honorary degree of Doctor of Science was conferred upon Walter C. O'Kane by the Ohio State University at the spring convocation June 13. This marked the eighth time that an honorary degree has been conferred and the first time that a biologist has been the recipient. Charles F. Marvin, Chief of the U. S. Weather Bureau, Washington, D. C. who received the same degree was the only other upon whom an honorary degree was conferred during the present year. Both are former graduates of the Ohio State University.

Effective May 16, Curtis P. Clausen, Entomologist, Bureau of Entomology who has been in charge of research for parasites of the citrus black fly at Kuala Lumpur, Federated Malay States, was transferred from the field to the departmental Service. In the new assignment Mr. Clausen will be responsible to the Chief of the Bureau for coordinating work of the several divisions and cooperating States concerned with the importation of beneficial insects and with investigations and work concerned with the breeding up for local control purposes or for interstate distribution of native and long established beneficial insects. He will also aid the chief in cooperating with the Plant Quarantine and Control Administration in the enforcement of the Insect Pest Act of 1905, particularly as it involves the interstate shipment of beneficial insects. Mr. Clausen's wide experience with parasites, especially his familiarity with the work in foreign countries, makes him well qualified to fill this new position. In connection with this assignment it is expected that Mr. Clausen will visit various field stations of the Bureau in order to become more familiar with the work that is being carried on.

Horticultural Inspection Notes

Mr. Chas. H. Baldwin succeeded Mr. B. A. Pyrke as Commissioner of the Department of Agriculture and Markets of New York on July 1.

Arizona quarantine order No. 4, which has heretofore restricted the importation of rooted or unrooted olive cuttings, was rescinded on February 19, 1932, according to Mr. George, the State Entomologist.

Canadian quarantine regulations (Nos. 10 and 19) issued March 29, 1932, prohibit the entry into British Columbia of gladiolus from the United States or from other provinces of Canada on account of the gladiolus thrips.

Canadian quarantine regulation No. 18, revised on April 8, 1932, prohibits the entry of wheat from Australia and Asia except under permit and certificate that the flag smut was not known to exist in the locality of origin.

Mr. L. M. Scott left New York the first part of June to take charge of the eastern section of the Canadian border inspection work, extending from Erie, Pa. to the Atlantic coast. Mr. Scott's headquarters will be at Rouses Point, N. Y.

Under the agricultural appropriation act for the fiscal year 1933, the name of the Plant Quarantine and Control Administration of the United States Department of Agriculture has been changed to the Bureau of Plant Quarantine.

During the latter half of May Mr. E. R. Sasscer of the office of Foreign Plant Quarantines visited the Mexican border for the purpose of conferring with the three district leaders on plant quarantine problems. Before returning to Washington Mr. Sasscer visited New Orleans and other Gulf Coast ports.

Mr. L. M. Ames of the United States Department of Agriculture is spending July and August checking on the nurseries which grow immune barberry and Mahonia plants for shipment into the thirteen States which are eradicating the susceptible kinds of barberries and Mahonias.

A called meeting of the National Plant Board was held at St. Louis on July 9 to discuss the European corn borer situation. A number of members of the Southern and Central Plant Boards were also in attendance. The United States Department of Agriculture was represented by Messrs. Lee A. Strong, L. H. Worthley, S. A. Rohwer, and D. J. Caffrey.

A survey of all commercial gladiolus plantings in California is being made by Agricultural Commissioners of that State to determine the exact distribution of gladiolus thrips. Infestations were recently found at several points in Los Angeles County, previous to the time that treatment for such bulbs was required.

The California alfalfa-weevil quarantine (No. 8) relating to intrastate shipping was revised on June 28, 1932. The regulated territory now includes the entire counties of Sierra, Plumas, Alpine, Alameda, and Santa Clara, and parts of the counties of Contra Costa, Lassen, Mono, San Joaquin, and Stanislaus.

A number of the more extensive Florida producers of narcissus bulbs conferred at Washington with members of the staff of the Bureau of Plant Quarantine on July 12, with respect to the control of Aphelenchus infestations. Subsequently, Dr. S. B. Fracker of the Bureau spent several days in Florida going over conditions with the members of the State Plant Board.

A quarantine relating to the cherry fruit fly has been issued by the Oregon State Department of Agriculture prohibiting the entry from Washington State of fresh cherries or boxes that have contained them, except under certification that the fruit originated in one of the 19 counties comprising central and eastern Washington, and that the boxes were dipped in hot water or steam. This order (No. 24) was issued June 20, 1932.

An extensive spray campaign as an added precaution for the control of the Mexican fruit fly, has been inaugurated by the State Department of Agriculture in the Lower Rio Grande Valley of Texas. A new bait spray, the active ingredient of which is nicotine sulphate, is being used. It is estimated that four million trees will be sprayed twice in this campaign. Mr. J. A. Alderdice has been appointed in local charge of this work.

Supplementing the amendment to the Federal narcissus bulb quarantine, to which reference was made in the last issue of the Journal, the Federal Department of Agriculture has issued two circulars entitled "Treatment and Pest Suppression Measures in Narcissus Plantings" (BPQ-337) and "Narcissus Inspection and Certification" (BPQ-338), respectively.

Mr. W. W. Wood of Detroit who has charge of the central district of the Canadian border inspection work, extending from Erie, Pa. to the eastern boundary of the State of Montana, was in Washington the early part of May and conferred with Customs officials concerning methods for cooperative relations with Customs inspectors along the Canadian border in the enforcement of plant quarantines. He spent the latter part of June and the first half of the month of July visiting various ports of entry in his district.

The California cherry fruit fly quarantine was revised on May 21, 1932 to include Benewah County, Idaho in the infested area, and to eliminate Lake County, Oregon, and Nez Perce County, Idaho, from the infested area. "The Oregon officials inform us," the announcement states, "that the cherry fruit fly has never been found in Lake County. * * * The Idaho officials inform us that the cherry fruit fly has been found in Benewah County and that the reported occurrence of that pest in Nez Perce County was apparently in error as indicated by recent surveys."

A meeting of the Eastern Plant Board was held at Philadelphia June 27, at which consideration was given to the anticipated revocation of the European corn borer quarantine regulations and the possibilities of retarding corn borer spread in view of the cut which has been made in Federal appropriations for this purpose. Representatives of the States of Connecticut, Delaware, Maryland, New Hampshire, New Jersey, New York and Pennsylvania, as well as of the Bureau of Entomology and of the Plant Quarantine and Control Administration, were present.

To cover the finding of *Helix pisana* in a small area in California near Seal Beach on the Orange County and Los Angeles County line State quarantine Regulations No. 5 has been issued effective July 1, 1932. Commenting on this regulation, the Chief Quarantine officer states: "It is understood that immediate measures are to be taken in an endeavor to bring about eradication and hence it is expected that the snail population in this area will be promptly reduced to a point where there will be practically no danger in connection with any commodities moving from the quarantined area, particularly when they meet the provisions of the quarantine."

The pink bollworm of cotton was identified about the first of June in cotton bolls secured near Miami, Fla., and the survey which immediately followed showed that the pest was present in a small patch of about two acres of cultivated cotton near Miami and in wild cotton in a section of Florida extending from south of Miami to Key West. This region is some 400 miles distant from commercial cotton plantings. The Federal Department of Agriculture and the State Plant Board immediately started measures to eradicate the infestation and prevent its spread. The Federal Department announced that Federal quarantine action does not seem to be necessary at this time.

The Secretary of Agriculture, Arthur M. Hyde, revoked the domestic European corn borer quarantine, effective July 15, 1932, and cancelled the regulations thereunder. The Secretary asserted that the reason for the revocation was the failure to obtain funds sufficient to maintain effective control. The press notice announcing the revocation stated that the field is now left open to the various States to prevent the further spread of the European corn borer if they desire to do so by any means at their disposal. The available Federal funds are being employed in scouting to determine the distribution of the borer. Other results of the Federal economy program have included a material reduction in the personnel of the projects relating to the gipsy moth and Japanese beetle, and the transit inspection work, as well as proportionally smaller reductions along other plant quarantine lines.

Mr. J. M. Del Curto reports that many horticultural sections of Texas are practically free of any insect pests whatsoever because of the fact that they are isolated or separated from other sections. These sections are maintained as "pest-free zones" under a very unique law which involves county court procedure. Such a pest-free zone has only recently been established in the Winter Garden area of Texas in a district which comprises five counties and approximately two hundred thousand citrus trees. Under this same law, local eradication projects are being carried on. Smith and Upshur counties are now in the process of cleanup procedure under this law and no sweet potatoes are allowd to be planted until both seed and ground have been approved. Dr. Emil Ludwig Schostag has been placed in charge of the Winter Garden Pest Free Zone area, and Mr. E. T. Crozier is in charge of the sweet potato weevil eradication campaign.

Prof. G. M. Bentley reports that 1,100 nurseries are being inspected in Tennessee this summer. Two inspections of each of the 96 greenhouses are also made every year. The first inspection begins in November and continues through December. The second inspection is made in March and April. Four inspections are made of the first and second potato crops. This work is confined primarily to six counties in the Cumberland Plateau, namely, Cumberland, Fentress, Scott, Morgan, White and Bledsoe Counties. In these counties the Irish potato is one of the leading crops and the soil and climate conditions are ideal for the growing of high quality potatoes with a splendid yield. There are some 125 receiving this certification. The sweet potato certification work has been in progress since March which began with the bedding of potatoes. This work is made up of six inspections: the dipping and bedding of the potatoes, two slip inspections, two vine inspections and the storage inspection. The inspections are made during the growing season excepting the storage inspection, which is made in January and February. There are some 300 receiving this service.

A meeting of the Western Plant Quarantine Board was held at Bozeman, Montana, June 9–11, 1932, the following States being represented: Arizona, California, Colo-

rado, Idaho, Montana, Nevada, Oregon, Utah, Wyoming, the Province of British Columbia, Canada, and Mexico. Lee A. Strong, Chief, U. S. Bureau of Plant Quarantine, W. W. Wood, Assistant Plant Quarantine Inspector, and Wm. C. Wood, Chief, Division of Classification, U. S. Post Office Department, attended this meeting and took an active part in the program. The subjects discussed included Mexican fruit fly control developments in Mexico and Texas, truck and automobile inspections, apiary inspection, necessity for basic investigation on the part of the U. S. Department of Agriculture in developing methods of weed control, and efforts to secure recognition by the Post Office Department of State quarantine orders and regulations in the case of parcel post mail.

In addition to the usual general resolutions, definite resolutions were passed requesting cooperation on the part of the U. S. Department of Agriculture in weed control investigations; requesting an early hearing of the Bureau of Plant Quarantine on foreign plant packing material; and requesting enforcement of the Lacey Act at maritime ports of entry. George L. Knight, Chief of the Division of Horticulture of Montana, was elected Chairman; Dr. F. E. Stephens, State Agricultural Inspector of Utah, was elected Vice-chairman; and A. C. Fleury, Chief Quarantine Officer of California, was elected Secretary-Treasurer for the ensuing year. George G. Schweis, Director of the Division of Plant Industry, Nevada, and A. C. Fleury, Chief Quarantine Officer of California, were selected as delegates to the National Plant Board.

Apiculture Notes

The annual summer meeting of the Colorado Honey Producers' Association was held at the Colorado Agricultural College, Saturday June 18th. About ninety persons were present from Iowa, Wyoming, Nebraska and Colorado.

Some damage has been done to comb honey in Colorado during the past few years by *Vitula edmandsii* Pack. The larva of this moth does considerable damage to sections of comb honey by eating the cappings, spinning slight webs and pupating in the empty corner cells. It is parasitized by *Nemeritis canescens* Gravenhorst. Reports of damage have thus far been limited to the stock of one producer. Damage is done in storage. Determination was made, of the moth, by the Division of Taxonomic Investigations, U. S. Bureau of Entomology.

Notes on Medical Entomology

E. C. Cushing, who has been spending the past two years in the Territory of Alaska in the study of the biology and control of the reindeer bot fly, has been transferred to Menard, Tex., where he will continue the research studies of the screw worm fly and other ectoparasites of domestic animals.

During the meetings of the American Medical Association at New Orleans, the U. S. Entomological Laboratory at Charleston, S. C., presented an exhibit on "Salt Marsh Sand Flies," featuring creosoted pine sap as a new insecticide. An exhibit was presented for the Washington office of "Myiasis and the Use of Maggots in Surgery." It was of much interest to the medical profession. It was timely in that motion pictures were being shown in two other locations in the building on the use of maggots in treating osteomyelitis.